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The Future of Sheep and Sheep Research

Proceedings of Saddle and Sirloin Seminar,
North American Livestock Exposition,
Louisville, KY, November 12, 1989

SADDLE AND SIRLOIN SEMINAR

THE FUTURE OF SHEEP AND SHEEP RESEARCH

at the North American Livestock Exposition, Louisville, KY
November 12, 1989

MODERATOR: Dr. R. D. Plowman
Administrator
ARS, USDA
Washington, D.C.

1:00 p.m. **Feeding and Forages**
R. M. Jordan, University of Minnesota

1:30 p.m. **Reproduction**
W. C. Foote, University of Utah

2:00 p.m. **Management**
C. V. Hulet, ARS, USDA, Las Cruces, N. Mex.

2:30 p.m. **Recess**

3:00 p.m. **Lambs and Wool**
J. M. Shelton, Texas A & M University

3:30 p.m. **Rapid Selection***
S. K. Ercanbrack, ARS, USDA, Dubois, Idaho

4:00 p.m. **Biotechnical Selection**
C. E. Terrill, ARS, USDA, Beltsville, MD

4:30 p.m. **Summary**
T. W. Perry, Purdue University

6:00 p.m. **Social Hour**
Mary Room, Executive West Hotel

7:00 p.m. Banquet in honor of Clair E. Terrill and the hanging of his portrait.

* Paper not available at time of printing.

THE FUTURE OF SHEEP AND SHEEP RESEARCH: FEEDING AND FORAGES

R.M. Jordan

It's a genuine honor to be at this gathering to pay tribute to Dr. Clair Terrill, sheep researcher and promoter nonpareil. Terrill provided a cohesiveness of effort, considerable focus and direction, and a sense of importance to sheep research for almost 55 years. His longevity and singleness of purpose are, in themselves, significant accomplishments. I suppose we could say, in jest, that he presided over the greatest decline in sheep numbers (from 53.9 million in 1941 to 11.5 million in 1988) in our history. But without Clair, we might have only 5.0 million sheep today.

My assigned topic, "Feeding and Forages". is one that I am comfortable with, since I have focused my research efforts on those two areas for over 40 years and, in the process, have become infatuated with the subject.

Most of us assembled recall the 1930's and 1940's, when sheep husbandry was more pastoral, ketosis was a plague as well as a mystery, water belly was routine in fattening lambs, sulfur was our best preventative for enterotoxemia, copper sulfate and Black Leaf 40 were our best anthelmintic, corn silage was "verboten", and lambs suckled for 6 months instead of 6 to 8 weeks as they do now. Despite our lack of technology, we had 50 million sheep, and producers made money.

Since sheep were a pastoral animal, sheep supplements were pretty much restricted to tonics and mineral supplements. During this same period, the veracity of those dispensing feedstuffs was suspect.

Then, as now, feed economy was paramount, and the focus was often on what it cost per day rather than on what an additive would contribute to economy of production.

University of Minnesota, St. Paul, Minnesota

The 1950's and 1960's found most sheep nutritionists devoting considerable effort attempting to determine what was the minimal effective level of DES implant, whether DES could be effectively fed, and which antibiotic, and at what level, would enhance lamb performance and reduce death loss. Many digestion trials were conducted to determine the effects of forage maturity, storage, level of feeding, and level of protein and added grains on diet utilization.

Pelleted diets emerged as a means of increasing feed intake, improving lamb performance, and enhancing the value of low quality roughages. While pelleting significantly improved high forage diets, it did less for high concentrate diets. The extensive preparation of forages prior to pelleting increased costs 25 to 40% and precluded use of pelleted forage under most circumstances.

In many respects, the 1950's and 1960's were the birth years of our modern feed industry. Purdue Mixture A initiated a rush to formulate supplements containing all the minerals, vitamins, and antibiotics known to be required. Since then, we have been attempting to include various additives that would improve upon a basic legume-grain diet and also be cost effective. Our success has not always been overly striking.

Since the ewes' diet constitutes about 75% of the total feed costs entailed in producing lambs, it follows that much effort has been expended on determining low-cost substitutes for hay and grain; amount of protein, energy, minerals, and vitamins a ewe actually needs; effects of undersupply or oversupply of nutrients; and factors that influence the ewe's nutritional needs. We now recognize that shelter from the elements and minimal activity (sheep in drylot) can reduce the energy requirements of ewes by 25 to 35%.

Choice of feedstuffs for sheep hinges on availability in a given area. In the Midwest, it's legume or legume-grass mixtures, and, in the range areas, more grass hay supplemented with legumes or "cake." Composition and intake, cost of supplementation, and the physical condition of available feedstuffs largely influence feed selection. The diet that is formulated should be determined by feed costs per unit of gain, labor and feeding facilities required to feed it, and physiological effects of diet components on the sheep. Unfortunately, diet choice is often based upon feed cost per ton, with little regard given to feed refusal, which, in itself, can change low feed costs to high costs.

Corn and oats, early-cut grasses, and legumes need little supplementation for ewes. But producers all too often rely upon hays of low quality, with disastrous results; and, when such hay is supplemented with high intakes of protein block, feed costs escalate. Actually, sheep are not the finicky eaters we once thought they were. Field beets, poultry litter, cull beans, cornstalks, straw, sprouted grains, etc., have all been used successfully as ewe feeds.

Relative merit of forage, grains, and supplements are influenced by nutrient intake; however, intake can mask the effect of composition, and vice versa. One of the major changes in sheep husbandry has been the practice of less frequent feeding of ewes per week and the feeding of much higher levels of grain. These changes have reduced costs appreciably and usually have improved production.

Morrison's TDN values have been the cornerstone of determining how best to feed sheep for about seven decades. We then related TDN to DE, and the simple calculation if DE x .82 to determine ME added further refinement in defining the energy requirements of sheep. The inclusion of NE requirements, as influenced by body weight, frame size, and weight gains, in the NRC (1985) publication is one of the most important contributions to sheep nutrition in 50 years. The TDN values provided a means to compare the energy value of corn and cabbages, but ME and NE values give us a preciseness not previously available. However, the use of ME and NE values by sheep producers is not widespread as yet.

The fifties and sixties brought forth ewe milk replacers that enabled producers to reap the benefits of the highly prolific Finn cross ewes. While quality of product (as influenced by drying temperature of milk) affected lamb performance, the composition of the replacer was equally critical. Milk replacers with 25% protein and about 30% lactose and fat have proven effective. Excess lactose causes scours, high levels of fat detract from ease of mixing, and excess protein escalates costs.

Recent research has focused on the effectiveness of ionophores, greater refinement as to the influence of protein level and by-pass protein on milk production, and the nutrient requirements of ewes nursing triplet lambs. The current suggested levels of protein seem adequate. When fed in conjunction with high corn diets, protein that is slowly degraded in the rumen has not improved performance when fed to either lactating ewes or finishing lambs. However, an improvement has been noted when such protein is fed in conjunction with barley. Both the carbohydrate and protein in barley are degraded more rapidly than is true for corn.

Pasture Forages

In my mind, no segment of sheep feeding lags more than the utilization and management of pasture forages. While most midwestern and eastern pastures are composed of cool-season grasses and soil pH dictates what type of legumes will flourish, producers have not expended sufficient thought, effort, or input into agronomic or livestock management that would enhance livestock production from pastures.

An experiment conducted at Minnesota (Jordan and Marten, 1988) characterized some old and some less well known pasture forages. When lambs are offered a choice of forage, there are definite differences in apparent palatability among species. Lambs much prefer alfalfa and red clover to birdsfoot trefoil and cicer milk vetch. Red clover has a higher percent of leaves than the other three species, but alfalfa is higher in CP than birdsfoot trefoil, cicer milk vetch, or red clover. The IVDDM of leaves of cicer milk vetch is lower ($P<.05$) than that of the other species, but its stems are reasonably high in IVDDM. And the entire plant is as high in IVDDM as alfalfa or birdsfoot trefoil but lower than red clover. Carrying capacity is the highest for alfalfa and cicer milk vetch, and, despite differences in palatability, CP content, and IVDDM, average daily gain and lamb gains per hectare did not differ among species.

The magnitude of the gain per hectare attained in these experiments attests to the potential for well managed pastures to contribute significantly to the efficiency of sheep production.

The Future

"As long as grass grows," the touchstone of sheep nutrition will be based upon forage. If the same genetic improvement and the same level of production-enhancing inputs (fertilizer, herbicides, insecticides, and plants per acre) had been applied to forage systems as have been applied to corn and soybeans, "tame" forages would produce three to five times more per acre than they do at present. I envision a significant improvement in forage yield and quality in the next decade.

In my view, adaptation of currently available husbandry-enhancing sheep technology in a complete systems approach by 50% of sheep producers rather than .5% will escalate productivity more than new discoveries. This is not meant to imply that if by-pass protein, ionophores, repartitioning agents, nitrogen "inoculated" roughage, feed intake stimulators, metabolic control agents, uterine environmental enhancers, and so on, prove to be cost-effective, non-hazardous to human health, practical in production, etc., they will not contribute to more efficient production. But a "technology discovery hiatus" appears to be waiting in the wings, spurred on by lack of research venture funding and lack of university focus on production agriculture. Prospects for production research in the immediate future are guarded.

Clair Terrill, you lived and worked in agriculture's golden years of exploration and discovery. Not all truths have been discovered, but your pioneering work in sheep genetics, your inspirational leadership, and your unbounded faith in the "old ewe" have hewn a path towards new successes in sheep production. For this, all sheep producers and sheep researchers are extremely grateful. We salute you on this day when your portrait will be hung amongst the most august group of livestock people in America's history.

SOME CONSIDERATIONS OF THE FUTURE OF REPRODUCTION IN SHEEP

Warren C. Foote

Consideration of the future of reproduction in sheep from any presumed perspective, encompassing both performance and research, is an interesting and intriguing challenge - the least of which is not where to begin and where to end.

Current as well as future reproduction performance in sheep has a broad base both in genetics and in adaptation to most environments of the world as indicated by the more than 900 genotypes recorded by Terrill (1979).

Reproduction can often best be expressed as a series of cycles. For this discussion it is defined as beginning with those processes required for conception, through the birth and development of the resulting offspring to its conception, if a female, or to its essential contribution to conception, if a male. This definition of reproduction provides for propagation of the species including related maternal attributes, all endocrine, physiological and behavioral factors, and all genetic and environmental influences.

Reproduction plays an essential role in the overall scheme of production. Without reproduction there can be no production. The level and efficiency of reproduction influence the rate of genetic improvement, at least in terms of generation interval and selection differential. From a management prospective reproduction is one of the several phases or components of production.

What is the reproduction potential of sheep and where are we on the scale in achieving that potential? Wilson (1968) estimated existing standards and biological ceilings for four groups of mammals (Table 1). Under the grouping for goats and sheep he estimated existing performance of 1.5 offspring per litter and one litter per year. Although this is within the levels possible for many breeds of sheep and production systems it is far above that achieved by most systems at present. Wilson's estimate of the biological ceiling was five lambs per litter and two litters per year or 10 lambs per year. Both of these components are possible genetically, but probably not in the same breed. There are breeds of sheep with the quantitative or qualitative genetic makeup to provide the required prolificacy. Several breeds of hair sheep have short postpartum intervals which allow for six-month lambing intervals, particularly near the equator. For example, 48% of a flock of the St. Croix breed of hair sheep at Utah (42° North Latitude) lambed at six-month intervals over a period of several years (Evans, 1987).

By comparison of goats and sheep to other species Wilson estimated the existing and biological ceilings for the rabbit as 15 and 48 offspring per year, for the pig, 18 and 44, and for the cow and buffalo, 0.9 and 1.4. Further use of information in the table shows that goats and sheep have achieved only 15% of their potential (biological ceiling) while the other three groups have achieved from 31 to 64%. This suggests that comparatively less progress has been made to date and, therefore, more progress is possible, or perhaps likely, in the future in goats and sheep compared to the other species. It is also likely that procedures used for the greater increases in the other species might be available for use in goats and sheep. Estimates are only estimates but these by Wilson appear reasonable and indicate upper genetic limits.

A production related goal mentioned in the Sheep Health Section of the National Wool Grower Magazine (1988) was one pound (.45 kg) of lamb produced per ewe per day per year. According to information provided by the Livestock and Meats Statistics (1989) the average for the same year was 0.135 kg. This may be an overestimate because of the method of calculation. According to these same statistics there were 1.06 lambs born (or docked or branded) in the United States for every ewe one year of age and older.

Performance in many cases is much better than these statistics. It also logically follows that performance is lower than these statistics in some considerable proportion of cases. Some farm flock producers with increased lambing frequency are weaning more than 3.0 lambs per ewe per year and some western range producers that have modified their management system to breeding on alfalfa fields or improved pasture and to shed lambing are regularly weaning 140-160% lamb crops at five to six months of age

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and at average weights of 45 kgs. or more. Most range producers recognize the importance of ewes lambing first at one rather than two years of age and of the advantage of twin rather than single born lambs.

Hulet and Price (1975) demonstrated the advantage in increased reproduction and lamb production of breeding ewes to lamb first as yearlings compared to lambing first at two years of age (Table 2). The younger ewes at first lambing out produced the older ewes at first lambing at each age measured including production of an extra lamb crop as yearlings. For example, for the period of three years of age and older the performance for the ewes lambing first as yearlings compared to two-year olds were fertility 97 vs 89%, prolificacy (lambs born) 158 vs 141%, lambs weaned 134 vs 115% and total weight of lambs weaned 48.5 vs 39.5 kgs.

The importance of both type of birth and type of rearing, which are products primarily of management, is demonstrated by some work we did several years ago under modified range conditions in southern Utah (Foote et al., 1981). The data are summarized in Table 3. The genotypes of dams involved were the straight bred Targhee, the Suffolk-Targhee cross and the Finnsheep-Targhee cross. The lambs resulted from top crossing to the Suffolk ram. The individual lamb performance is greater the smaller the litter size born and reared. That is, weaning weight at approximately five months of age and average daily gain from birth to weaning are greater for lambs born and reared as singles (46.0 and .273 kgs) than for lambs born and reared as triplets (34.6 and .209 kgs, respectively). The increase in lamb production came, of course, from ewes that both produced and reared more than one lamb. Expressing performance of ewes that produced and reared single lambs as 100%, performance of ewes that produced and reared twins was 167% and ewes that produced and reared triplets was 226%. By contrast the performance of ewes producing twins or triplets and rearing only one dropped to 90 and 87%, respectively.

Table 1. Existing standards and biological ceilings for reproductive efficiency (modified from Wilson, 1968).

Parameter	Rabbit	Pig	Goat and sheep	Cow and buffalo
Existing:				
1. No. of offspring per litter	5	9	1.5	1.0
2. No. of offspring per year	15	18	1.5	0.9
Ceiling:				
3. No. of offspring per litter	12	20	5.0	1.2
4. No. of offspring per year	48	44	10.0	1.4
2 as % of 4	31	41	15	64

Management under modified range conditions such as those used in the above study is quite common in the intermountain area where high mountain summer pasture is a part of the grazing system. Management, especially at key times, particularly to provide for nutrient requirements and adequate animal health, is an essential ingredient.

An important consideration under these conditions and others where restrictions to management options are imposed is that the maximum is not the optimum because of environmental or other factors limiting management with economics being a very significant determining factor. By the same logic, new management approaches must continue to

Table 2. Lamb production of Targhee range ewes bred and selected on pregnancy as compared to ewes lambing for the first time as 2-year-olds (modified from Hulet and Price, 1975).

Management practice	Age of ewe (Years)	Ewes lambing (%)	Lambs born (%)	Lambs weaned[1] (%)	Total lamb weaned (kgs.)
Lambed 1st as yearlings	1	100[2]	111	83	25.4
	2	98	143	115	38.1
	3 or over	97	158	134	48.5
Lambed 1st as 2-yr-olds	1	0	0	0	0
	2	88	102	82	26.3
	3 or over	89	141	115	39.5

[1]Percent lambs born or weaned of ewes bred.

[2]Only those ewe lambs diagnosed pregnant were saved.

Table 3. Average lamb performance when classified by type of birth and type of rearing (modified from Foote et al, 1981).

Type of birth & rearing[1]	Number	Weaning wt. (kgs)	Avg. daily gain (kgs)	Body Conditions score[2]	Wt. of lamb weaned per ewe lambing (kg)	% of SS
SS	1668	46.00	.273	2.30	46.0	100
TS	1405	41.40	.250	2.61	41.4	90
TT	2293	38.50	.227	2.88	77.0	167
TrS	153	39.95	.245	2.67	40.0	87
TrT	203	37.31	.223	2.95	74.6	162
TrTr	95	34.63	.209	3.15	103.9	
226						

[1]S = Single, T = Twin, Tr = Triplets (TS indicates lamb was born a twin and reared a single).

[2]Score of 1-5; 1 equals highest and 5 equals least body condition.

be considered in an effort to further improve both the level and efficiency of reproduction and thus increase profit. Management practices must also be developed with sensitivity to other major factors in sheep production such as predator control, public land use, persons to care for sheep and interest rates. Some of these are more regional in their importance than others but each significantly influences the management practices to be used and the economically optimum reproduction performance to be achieved.

Consideration of programs for the future, both in terms of technology to control and regulate reproduction processes as a result of research and related application to the industry and in terms of the economics and producer acceptance suggests the following categories of things that cannot and can be changed.

1. Things that cannot be changed. A certain amount of time is required to complete the essential endocrine and physiological reproduction processes. Six months appears to be the lowest common denominator. Six months of age is the shortest, most useful age to breed ewes for first lambing to fit into a once a year lambing schedule. Six months is the shortest cycle for completion of a pregnancy and rebreeding (conception).

The uterus and the udder both impose severe physical-physiological limitations on reproduction in sheep. There may also be a behavioral limitation in terms of the number of offspring a ewe can care for. Significant genetic variation occurs for each of these within and between breeds. Each limit the number of offspring that can be accommodated at one time. It appears unlikely that these conditions can be appreciably altered, except to increase the production of milk and the lactation curve.

2. Things that can be changed. Although often considered to be too slow, traditional genetics can be used to make most of the changes required to achieve most goals in reproduction performance. It has the advantage of being a predictable, permanent change. Some of these changes are being achieved through crossbreeding and the synthesis of new genotypes and through selection within existing breeds.

Reproductive endocrinologists and physiologists will be forever determining the mechanisms of control of reproduction processes and of other processes that influence reproduction. This is critical to continued improvement in performance. However, enough information is now available, or is imminent, to optimize reproductive performance for most production-management systems, particularly when considered as a complement to genetic improvement, in terms of age at first breeding, lambing frequency, fertility and prolificacy. Adequate information is also available on animal health and nutrition management to eliminate lamb and ewe mortality as serious threats to either reproduction or production. The incorporation of these technologies into management practices and their use in many management systems would result in dramatic changes in reproduction performance.

For example, under optimum conditions of semi-intensive management systems the following level of reproduction performance can be achieved. Beginning with the prolificacy of 2.5 lambs per lambing and three lambings in two years (potential of 3.75 lambs per year), 97% fertility (3.64 lambs) and 95% lamb survival, yields 3.46 lambs per ewe per year. This is less than levels reported by some producers but seems to be a reasonable estimate of what is currently achievable under this type of management system.

However, as mentioned earlier, some physical or environmental conditions dictate certain components of management which limit reproduction performance. Many, if not most, extensive western range operations require once a year (Spring) lambing. Management can be changed to optimize reproduction at that time but it cannot be effectively shifted or the frequency increased.

It is also important to recognize that it is under such environmental conditions that sheep evolved and where they continue to make perhaps their most significant and unique contribution to food and fiber production. Small ruminants are unique in their ability to fit their reproduction and production cycles into the annual feed production cycle; to self harvest and effectively utilize renewable feed resources that would be largely or totally wasted by other species in their attempt to reproduce. When we move sheep into more intensive production-management systems we require that they compete with species that are often better fitted for the management systems involved. The reality is that sheep compete with other species and contribute to man's well being under an incredible array of environmental and management conditions.

We have now entered into an era of biotechnology that holds promise of quantum leaps in reproduction and reproduction related

functions. Some of these are not so much new as they are representative of continuing updates in older procedures. The final usefulness or application to increasing performance for most of these biotechnologies have yet to be determined. But they offer exciting new approaches and certainly potential short cuts, both genetic and management, to improved reproduction. Some are still in the "embryonic" stages of development with the limits of their capabilities yet to be determined and the possibilities for application yet to be explored.

Sixteen biotechnologies are listed here and commented on very briefly for the primary purpose of example. Many of these can be further divided into additional biotechnology entities and there are surely others not mentioned that are just as applicable.

1. Artificial insemination (AI). The main advantages include the ability to greatly increase the number of offspring produced from a superior sire, it is a relatively simple procedure, and fertility can be similar to natural mating under some conditions. In addition, the technique can be applied to many sheep enterprises.

The disadvantages include the fact that the gene complement of only the sire is transferred compared to the full gene complement as in the case of embryo transfer. Also, results from the traditional method of insemination into the opening of the cervix and the use of frozen semen are usually low. Although fertility is increased, the cost of intrauterine insemination using the laparoscope is relatively high.

Insemination can be made at two sites; the opening of the cervix (os cervix) or directly into the uterine horn. Semen cannot be routinely deposited deep in the cervix or into the uterus through the cervix as in cattle and goats because of differences in cervical morphology.

Insemination into the opening of the cervix is usually accomplished with a speculum and light and a pipet or insemination gun. The number of sperm inseminated varies a great deal but if frozen semen is used, from 0.2 to 0.3 billion sperm should be used. If fresh semen is used, approximately one-half of that used for frozen semen is usually considered adequate. The resulting fertility usually varies from approximately 10 to 30% for frozen semen and from 40 to 60% for fresh semen.

Insemination into the uterine horn is accomplished with the laparoscope inserted through the body wall immediately in front of the udder. Using this method approximately 20 million frozen sperm or 10 million sperm from fresh semen are usually inseminated directly into each horn. In either case fertility rates of 60% or higher are frequently obtained. Additional numbers of sperm are required for breeding superovulated ewes, regardless of the method of insemination, if acceptable proportions of ova are to be fertilized. More information on artificial insemination and related technologies can be found in a recent book by Evans and Maxwell (1987).

2. Synchronization of estrus and related ovulation during the breeding season. This procedure is useful to facilitate AI, embryo transfer or to concentrate the time of breeding for production and/or marketing of lamb. However, it may reduce fertility, is relatively expensive and requires additional management support.

Synchronization can be achieved by administration of a progestogen hormone for 10 to 14 days via a subcutaneous implant or an intravaginal sponge or hormone containing device. It can also be achieved by two PGF2α injections of about 15 mg each at 8 to 10-day intervals or a combination of progestogen and PGF2α.

Usually 95% or more of the ewes come into estrus primarily between 24 and 36 hours after the end of the hormone treatment.

3. Superovulation. The primary use of this procedure is to increase the number of embryos available for collection. Some effort has also been made to increase the proportion of twinning by adjusting the level of hormones used but with little success because of the large variation in ovulation response.

Two gonadotrophic hormones are used to increase the number of follicles developed and ovulated. Pregnant mare serum gonadotrophin (PMSG) is administered as a single injection of 800 to 1200 I.U., 24 - 36 hours before the end of the progestogen treatment or the second prostaglandin injection. FSH is administered at 12-hour intervals for three or sometimes four days with the total dose of about 24 mg equivalents. The first injection of FSH is usually given 24 hours before the end of the progestogen treatment or the last prostaglandin injection. More sophisticated hormone treatment schedules are sometimes used. These include cocktails consisting of FSH and/or PMSG and GnRH. The resulting ovulation rate for all of these treatments usually averages from 5 to 10.

4. Embryo transfer. There is a very significant potential for practical application of this technique. It can be used to extend the genetics of superior ewes, to develop or accelerate development of viable populations from genotypes with limited or otherwise endangered number of females and to provide for development of specific pathogen free flocks and aid in preventing disease transmission. This procedure will facilitate international movement of germ plasm and generally reduce the cost and increase the convenience of movement of germ plasm.

Our cooperative work with Veterinary Services, Animal and Plant Health Inspection Services (APHIS), USDA using embryo transfer to determine the vertical transmission of scrapie has shown that embryo transfer is the most effective procedure to prevent scrapie transmission. A program has been developed, referred to as risk reduction procedure (RRP), based on these results and other available information to import new germ plasm from sheep and goats into the United States. These imports are planned to begin in 1989 and include embryos from dairy sheep, Boer goats and Cashmere goats. The imported embryos will be industry financed and owned and used to develop specific segments of the sheep and goat industries. Some of these same procedures are being used by producers to develop scrapie-free flocks as a scrapie control measure (Foote and Pitcher, 1989 and Foote et al., 1989).

Access to embryos has also greatly facilitated research and development of procedures for cloning, sex determination, and gene transfer. These are mentioned separately, later as biotechnologies.

The disadvantages in the application of embryo transfer include cost and the difficulty of identifying truly superior dams to serve as donors.

The procedures outlined earlier for estrus synchronization and superovulation are used to produce an increased number of embryos and to assure the proper timing among donors and recipients for collection and transfer of embryos.

Access to the reproductive tract for both embryo collection and transfer is gained via laparotomy or laparoscopy. Laparoscopy is a relatively new technology which provides access to the reproductive tract for both collection and transfer of embryos that reduces the occurrence of adhesions and, therefore, increases the number of collections that can be made from donor animals. Embryos are usually collected at five to six days of age at which time they are located in the uterine horns. They are flushed from the uterus with flushing media via a cannula or Foley catheter. Some estimated success rates related to embryo work are shown in Table 4. For more information on embryo transfer see Foote et al. (1989).

5. Freezing gametes and embryos. Freezing of sperm, oocyte and embryos has increased their potential use in sheep production. Freezing makes it possible to obtain germ plasm at the time most convenient for collection and to use it at the times most convenient. It provides for long-term storage. Freezing and thawing does not significantly reduce viability.

6. Pregnancy diagnosis. Pregnancy diagnosis can be a very important management tool because it provides for accurate estimates of fertility and it allows separation of the flock into pregnant and non-pregnant groups for more effective management.

There are several methods of pregnancy diagnosis. Two methods will be mentioned briefly here. The first is the use of painted teaser rams to detect ewes returning to estrus after the end of the breeding period. Careful management and observation can result in accuracy of 80% or higher and it can be completed during the length of the first estrous cycle after the end of the breeding period.

The second method uses the principle of ultrasound. Ultrasound equipment designed specifically for use in sheep is relatively inexpensive and is simple to operate. Most equipment is designed for use between about 60 and 120 days post breeding. Use by properly trained and experienced operators results in accuracy greater than 90%.

7. Hormonal induction of estrus and ovulation. This procedure can be useful in overcoming the limiting influence of photoperiod resulting in seasonal anestrus, in shortening the postpartum interval, and in inducing precocious puberty. Its use extends the period over which embryos can be collected and transferred and it provides for the production of extra lamb crops.

Hormonal induction using the same procedures outlined earlier for estrus synchronization and superovulation are effective and most commonly used. PMSG is the gonadotrophin most frequently used to induce estrus and ovulation and is administered 0 to 36 hours

prior to treatment with a progestogen or $PGF_2\alpha$. The level is reduced to approximately 400 to 600 I.U. to avoid superovulation.

It is important to note here that very significant progress is being made using melatonin to initiate breeding during periods of seasonal anestrus in the ewe (Stellflug et al., 1988) and to overcome seasonal influences on reproduction capability in the ram (Fitzgerald et al., 1988).

8. Sex determination. The obvious and real advantage of this technology is to know the sex of the offspring, preferably in the pretransferred embryo. Technology is now available to accomplish this.

One method that is 100% accurate is cytogenetic analysis of a small portion of the embryo usually from the blastocyst, pre-hatching stage. The development of a karyotype and identification of the sex chromosomes is a definitive analysis. There is reduced viability using this procedure. Another procedure also with 100% accuracy employs the use of a genetic marker to sex embryos. The advantage of this procedure is that it requires only approximately five cells from the blastocyst. The DNA is amplified using polymorphism chain reaction (PCR) and sex determined by electrophorizing this sample against a known genetic marker for sex. This procedure has been successfully used in cattle (Bondiolli, 1989) but has not been reported for sheep.

For several decades efforts have been made to separate sperm into those bearing y and x chromosomes as a method to produce either male or female offspring on demand. The validity of such a procedures is yet to be adequately demonstrated.

9. Invitro fertilization (IVF). IVF has been accomplished in sheep. (Cheng et al., 1986; Crozet et al., 1987; Madison, 1988) However, its use in the improvement of sheep reproduction or production is still not available. The technology involved increases the options for obtaining offspring from genetically superior or otherwise unique animals that would not be possible other wise. Perhaps of more importance it provides for fertilization using sperm or oocytes that have been genetically manipulated.

10. Cloning of embryos. Cloning or producing genetic replicates or copies of an embryo has been done using several techniques. One of the earliest used, but one that is limited to approximately four copies involves physically dividing

Table 4. Estimates of overall average responses from embryo transfer in sheep[1] (from Foote et al, 1989).

	Ova produced (super-ovulation)	Ova fertilized (embryos)	Embryos collected	Trans-ferable embryos (estimated viable)[2]	Lambs produced[2]
Percent	---	90	60	95	60
Number	10	9	5	5	3

[1]This is an estimate made by the authors from their experience and that of others under optimal field conditions. The values may vary markedly from one animal to another within a group and from one group of donor ewes to another. Factors such as age, breed and season of year have a significant influence on response.

[2]These values are based on fresh (unfrozen) embryos. Only a small amount of informa tion is available on frozen sheep embryos but freezing reduces these values.

the embryo. In the morula or blastocyst stage the embryo cells are still undifferentiated, therefore, one-half or one-fourth of an embryo can develop the same as the whole embryo.

One variation of another technique is to take cells from an embryo and insert them individually into single cell embryos from which the pronuclei have been removed. The resulting embryos will have identical genetic nuclear material and, therefore, be clones. The number of clones could be greatly multiplied by using cells from second and later generation embryos.

11. Gene transfer. This technique has been developed and applied using microorganisms such as bacteria into which genes from higher animals such as mammals have been obtained. The genes are really multiple copies of a fragment of chromosomal DNA containing the locus where the gene is located.

An example of application of this technique is the transfer of the gene for bovine growth hormone to microorganisms for the production of somatotropin. The somatotropin administered to cows significantly increased milk production (Bauman et al., 1985). Butler-Hogg and Johnsson (1987) administered bovine growth hormone to lambs and measured its effects on carcass composition and related traits. The gene for the growth hormone has been transferred into mice and some other mammals with spectacular increases in size. Such animals are referred to as transgenic.

12. Gene mapping and gene probes. New technology including the use of restrictive fragment length polymorphism (RFLP) procedures which involves the use of restriction enzymes to split chromosomal DNA into different fragment lengths and to replicate and store them in bacteria makes it possible to prepare maps of the location of specific genes. A chromosomal DNA fragment containing a specific gene can be used as a genetic marker or gene probe to identify the allelic forms of the gene in live animals. This makes it possible to determine the presence of specific gene alleles in breeding animals and aid in genetic selection for increased production and also to eliminate genetic diseases and to test for genetic susceptibility to specific diseases.

As an example, a group at Utah State University (Bunch et al., 1989) are developing sheep-specific gene probes using information developed for humans together with relevant techniques. A major objective of this work is to identify the location of the gene for the Spider Lamb Syndrome and develop a gene probe to identify sheep with the recessive or dominant allele. Such a test would greatly reduce the complexity and time requirement to eliminate the recessive allele which appears to be responsible for the occurrence of the disease.

Another example involves the genetic susceptibility of sheep to scrapie. Susceptibility relates to the length of the incubation period. Sheep with the allele for short incubation (usually from two to five years) are considered susceptible to the disease because it is expressed during their lifetime. Sheep with the allele for long incubation are considered resistant to scrapie because they die from other causes before the incubation period is completed and the disease is developed. Hunter, et al. (1989) have developed a gene probe for sheep for the alleles for length of incubation of a known form of this gene which is either the same as or is very closely associated with the PrP or Prion gene. We are collaborating with the group to extend the development and testing of this probe in U.S. breeds of sheep and strains of the scrapie agent. It is hoped that this technique will aid in the selection of sheep with the long incubation period and thus assist the sheep industry in the control of scrapie.

13. Cytogenetic analysis. The development of karyotypes and associated idiograms of chromosome morphology has greatly aided the determination of relationships among species, and their evolution, particularly in sheep and goats (Bunch et al. 1976a and 1976b). This technology has also been used to identify the cause of certain diseases resulting from chromosome inversions, translocations and deletions. An example of this is the Robertsonian translocation condition in cattle resulting from the translocation of chromosome 29 to chromosome 1 (Gustavsson, 1979).

More recent techniques such as G-banding, R-banding, C-banding, Nuclear Organizer Regions (NOR's), etc. have greatly increased the ability to identify chromosomes and their parts and, therefore, increase the use of this technology as an analytical tool.

14. Radioimmunioassay (RIA). This procedure for measuring minute amounts of a wide variety of reproduction related and other hormones has become the standard procedure for research and in many diagnostic tests. During the last approximately 25 years this technology has been particularly valuable in research in endocrinology of reproduction. In nearly every case it has replaced the more expensive and less

accurate and sensitive bioassay procedures. In addition it has provided for the measurement of many hormones that would be impossible to measure by bioassay. Other procedures such as Enzyme Linked Immunoabsorbant Assay (ELISA) are also proving useful in hormone analysis and may replace RIA in many cases.

15. Blood protein polymorphism analysis. This procedure is based on electrophoresis separation of the different polymorphisms of blood protein components such as Hb, transferrins, and esterases. These forms are very specific and represent allelic forms in the animal. They have been useful in determining inter and intra species evolutionary patterns and relationships (Wang, 1988).

In a more applied manner they are useful in determining parentage in specific cases where a parent is unknown or questioned. In a recent study (Wang and Foote, 1989) four blood protein polymorphisms were involved to estimate their usefulness in determining parentage in sheep. The limiting factor in definitive determination is that false parents as well as the true parent may have patterns that are compatible with the offspring and the other parent. In these cases the true parent cannot be determined. However, the true parent was identified in 67% of the cases analyzed and in no case was the true parent excluded. These same results were reported earlier by Stormont (1968) for horses. It was interesting, also, to note that in the work with sheep in 9% of over 100 offspring studied, errors in recording or identification of true parents were identified and substantiated.

16. Ultrasony. As mentioned earlier this technology has provided a standard procedure for pregnancy diagnosis in sheep. Real time ultrasound was initially developed for use in human medicine, but is now applied to reproduction research, body composition and carcass quality, and also management in sheep and other animals. From a reproduction-management point of view this technology allows for early analysis for pregnancy in sheep and the determination of the number of fetuses. From a research perspective real time ultrasound provides a means of monitoring ovarian changes such as those involved with follicular development and ovulation and the monitoring of fetal and placental development and their relationships to causative factors influencing their development. Such an example is found in the use of real time ultrasound in determining the influence and time of impact of poison plants on development of the conceptus (Panter et al., 1987; Panter et al, 1988).

Regardless of how significant and unique new biotechnologies are in their contribution to reproduction each must at some point function in an otherwise traditional genetic setting adapted in large measure to demands of the environment. Economics will usually make the final decision as to the usefulness of new biotechnology, as it has of biotechnology of the past, to the improvement of reproduction in any or all of its aspects.

At best, this paper provides only sketches of what can and should be expected of the future in terms of reproduction in sheep. By traditional genetic restructuring, such as crossbreeding and selection, we can continue to increase sheep's ability to breed throughout the year at latitudes away from the equator, we can continue to increase prolificacy, and we can develop and apply management practices that will increase ewe and ram fertility and will provide for increased survival of the resulting offspring. Endocrine and other management interventions can be used to further provide for increased reproductive performance within the limits imposed by economics.

At present under some commercial sheep production systems, and within the capability of many more, as many as four lambs are being weaned each year for each ewe in the breeding flock or that is exposed for breeding. This involves special management practices including artificial rearing of some lambs. This represents 40% of the biological ceiling estimated by Wilson (1968) and approximately four times that of the estimated current average for the United States of 1.06 lambs at birth or at docking, for each ewe one year of age and older. This suggested currently achievable four lambs per ewe per year when weaned at 45 kgs more than provides for the .45 kg of lamb per ewe per day suggested by the National Wool Grower.

What is reasonable reproduction performance for the United States by the beginning of the twenty first century? Sheep managed under extensive range conditions with little or no opportunity for improved management at breeding and at lambing except the provision of at least minimal requirements for nutrition and protection against disease should wean, at approximately five months of age and 45 kgs, 1.20 to 1.40 lambs for each ewe exposed for breeding. Ewes under modified range conditions, where more prolific genotypes can be used and management at breeding and at lambing can be improved, should wean 1.60 to 1.80 lambs per ewe exposed at the same age and weight mentioned above. Semi-intensively and

intensively managed ewes where increased frequency of lambing is possible together with other management factors to maximize reproduction should wean 3.5 to 4.0 lambs for each ewe exposed for breeding.

Will these levels of reproduction be achieved by the year 2000? No. There are several reasons for this. One reason is that much of sheep production in the United States is part time not full time. Also, sheep are often regarded as supplemental or secondary rather than as primary enterprises, with a role of utilizing feed resources not used by other species. For these reasons financial resources are usually not available to develop and maintain the levels of management required for improved reproduction. In such a role investments are usually not made for the purpose of increasing production.

However, the main factor that has limited improvement in reproduction performance in sheep is the attitude of most producers to new technology. A broad and flexible array of technologies are available to the producer that could very substantially increase performance and the resulting profitability. Why isn't he or she using them? Many are and in time many more will.

In the meantime sheep have the greatest capability, including adaptability, to reproduce under the varied environments involved. They can complete one and often more than one reproduction cycle that is adapted to and takes best advantage of the annual feed production cycle, with little or no assistance by man. And they can respond to improvement in management with increased reproduction to the point where they are competitive under intensive productive systems with species developed more specifically for those production systems.

Considering future reproduction in sheep on a global basis, perhaps the most significant point is that they will continue to perform efficiently under the whole spectrum of environmental conditions in which they exist including and perhap most importantly conditions of environmental stress and severe nutritional and animal health limitations. And as mentioned earlier, they will respond with increased performance to improved management.

In this symposium we have attempted to look into the future. But whatever we hope for in the future must be based on the accomplishments of the past and where we are at the present. Dr. Clair Terrill, whom we honor at this symposium, has made many of the contributions upon which our expectations of the future are based.

Clair Terrill received his training and began his contribution to sheep production at a unique time and in a unique circumstance. Although destined to become a geneticist he was trained as a productive physiologist as one of a handful of students trained in the early and mid 1930's at the University of Missouri by Dr. Fred F. McKenzie. These men were Clair E. Terrill, Ralph W. Phillips, L. E. Casida, F. N. Andrews, J. C. Miller and Victor R. Berliner. Individually, and as a group, these men have made an inestimable contribution to the advancement of livestock production in the U.S. and throughout the world.

Clair Terrill is unique in still another way. He never quits. Beginning with his early work on ovulation (McKenzie and Terrill, 1937) he has continued to contribute as a scientist, an administrator, an advisor, a mentor, an advocate, and a friend to hundreds of us. And each of us is better for it. His work, so far, has spanned over 55 years and we are grateful that he is still contributing.

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MANAGING SHEEP TO OPTIMIZE PROFIT

C. V. Hulet

INTRODUCTION

Sheep production is one of the oldest human agricultural enterprises. Management techniques for improving performance date from the earliest flocks. In the beginning and for hundreds of years, improvements in management were entirely dependent on the observational skill or "eye of the shepherd." Fifty years ago, fall-lambing was limited mostly to Dorset sheep. Range sheep operators wanted only one lamb per ewe. Most of the extra lambs were sacrificed and ewes were not bred before they were 18 months of age. A sick sheep was considered a dead sheep.

Rapid progress has been achieved in recent years with the application of scientific methods. We have witnessed great changes in management goals and practices. Large flocks of ewe lambs lambing at about 12 months of age have weaned 120-140% lamb crops. Numerous flocks in accelerated lambing programs are averaging about 3 lambs weaned per ewe per year. One intensively managed flock in Montana reported weaning an average of 4 lambs per ewe in 1988. Average daily gain has also improved and the weight of market lambs has increased about 1 lb. per year over the past 30 years.

A vast library of knowledge has been compiled on the basic physiology; endocrinology; food ingestion, digestion, metabolism and nutritive requirements; genetics; biological nature of infectious disease; life cycles and destructive impact of parasites; behavior; stress factors and predation of sheep. These scientific data housed in the research literature of the world provide the basis for modern sheep management. This brief presentation can only highlight some of the more significant management principles and procedures.

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GENERAL PRINCIPLE OF GOOD MANAGEMENT

Optimum reproductive efficiency, growth rate and freedom from disease can only be achieved in a comfortable, clean, uncongested environment. Because the maximum may be too costly, the best approach is to seek for the optimum when one considers both cost and performance. This will vary greatly among geographic locations and management options.

This is not an economic analysis of management alternatives but is intended to focus on relatively new or less well-known, under-used, or less understood, management factors which might impact the future productivity and profitability of the sheep enterprise.

INCREASED RATE AND EFFICIENCY OF GAIN

Efficiency of gain is related to the amount of weight gain made by a lamb per unit of feed consumed. Ercanbrack and Knight (1988) selected for rate and efficiency of gain based on lamb performance during a 16-week test period. The superiority in efficiency of lambs from the selected line over control lambs increased 3.3 percentage points annually over the 4-year study. Selected lambs were about 23% more efficient than controls at the end of the study. This means that they were producing about 23% more profit per day from gains than control lambs. With this

kind of production efficiency possible, it would be incumbent on management to obtain appropriate breeding stock and manage market lambs for efficient gain. Other Dubois studies have shown that young lambs gain much more efficiently than older lambs. This finding suggests, and the Dubois station research demonstrates, that young lambs can be fed and marketed much more economically than older lambs.

Another approach to improving efficiency of gain is through crossbreeding. The correlation between rate and efficiency of gain is well known. For example, the Suffolk is clearly recognized as a superior breed for rate of gain. In most tests, Suffolk-cross lambs have out-gained crosses derived from other breeds (Neville et al., 1958; Bradley et al., 1972).

Because of the high cost of maintaining breeding stock to produce market lambs, increasing slaughter weight of lambs can result in more efficient meat production. Heavier lamb carcasses are generally thought to be overly fat and wasty. However, the large, slow-maturing range breeds are making efficient lean gains at weights well above 110 lbs. Studies at the Dubois Sheep Station have shown that slaughter weights of Rambouillet, Targhee and Columbia ram lambs may be increased to 140 lbs. and ewe lambs to at least 125 lbs. without significantly decreasing the percentage of lean meat (Hulet and Ercanbrack, 1983). Panel taste scores for flavor, tenderness and consumer acceptance tests in Utah and California revealed that consumers liked cuts from heavier carcasses as well as lighter carcasses (Mendenhall and Ercanbrack, 1979). Slaughtering and processing costs per pound of meat are reduced at heavier weights since the costs to slaughter large and small lambs are similar. The historical average increase of about one pound per head per year in slaughter weight suggests that the more economical production of larger lambs will continue in the future.

EARLIER LAMB PRODUCTION

Breeding Ewe Lambs

The management of ewe lambs appears to be a logical starting place to improve management of reproduction. With few exceptions, ewes should be bred, selected and managed to lamb first at 1 year of age.

Three distinct advantages to breeding 7- to 8-month-old ewe lambs to lamb at about 1 year of age are: (1) reduced maintenance costs before the start of production; (2) shortened generation interval that results in more rapid genetic gains from selection and (3) increased lifetime production (Briggs, 1936; Evans et al., 1975; Hulet and Price, 1975).

Four important factors influencing fertility of 7- to 8-month-old ewe lambs are: (1) the size and condition of the lambs at breeding time; (2) the breed and breeding of the lambs; (3) the season of birth and (4) the time of year ewes are bred. As body size varies with breed, it appears that one can expect a favorable breeding response when lambs have reached about 65% of mature body weight. Good condition reflects the health, vigor and physiological well-being of the lamb and is positively correlated with the estrous response. Stoerger et al. (1974) found that a 50% roughage ration was optimum for maximum reproductive performance in ewe lambs.

Great variation among breeds can be observed in age at estrus as shown in the following table. Puberty probably has a moderate heritability. One group of Targhee ewes selected for early puberty for 8 years was compared with another similar group of Targhee ewes not selected for early puberty. The lambs were born, reared and managed at the Sheep Station under similar conditions and kept together in one flock after weaning. They were placed in breeding at about the same time and exposed to fertile rams for about 45

days. Fifty percent of the select Targhees, but only 20% of the unselected group conceived (Hulet, unpublished).

Roger Land (personal communication), University of Edinburgh, Scotland, selected rams in two directions for testis size. After only 2 years selection, the female offspring of the rams selected for large testis size reached puberty at a significantly younger age than female lamb offspring of rams selected for small testis size. Puberty in the male and female may be associated with both testis size and ovarian weight.

Rydberg et al. (1976) showed that time of birth and season of breeding influence conception rate in lambs. In their breeding study of Finn-cross ewe lambs born in February and April, they observed that the lambing and lamb crop percentages of all ewe lambs (combined ages) exposed September 5 to October 9, October 30 to December 3 and December 24 to January 27 were 30, 60; 100, 160 and 96, 141, respectively. The effect of month of birth on reproduction was demonstrated by the lambing performance of the February- and April-born lambs exposed to rams during the three breeding periods listed above. February-born lambs had lambing and lamb crop percentages of: 66.7, 111.1; 100, 188 and 95.5, 150 for the early, mid-season and late breeding periods, respectively. These results can be compared with those for the younger, April-born lambs that had lambing and lamb crop percentages of: 8.3, 16.7; 100, 138 and 95.5, 135.7 for the three breeding periods, respectively. These results indicate that ewe lambs have a higher fertility rate if bred during the middle of the breeding season and that February-born lambs have the advantage over younger lambs.

Work done by Foote and Matthews (1969) clearly showed that puberty can be accelerated by use of hormones. However, as yearling ewes must have adequate size to bear normal healthy young and produce enough milk to nourish them, under most circumstances, a better management practice would be to put this size on the lambs early in life. This management practice would then enhance the occurrence of estrus (Allen and Lamming, 1961; Hulet and Price, 1975) and in most instances eliminate the need for use of exogenous hormones. Possible exceptions are slowly maturing breeds such as the Columbia, Targhee and Rambouillet. However, recent studies at Dubois indicate that Rambouillet lambs which have been given proper nutrition and selected for high lamb production are lambing at a high rate (70 - 75%) at one year of age.

An excellent management tool that can be used in conjunction with breeding ewe lambs to improve production efficiency is pregnancy testing. Fertility is usually lower in lambs than in mature ewes. However, unlike mature ewes, non-pregnant ewe lambs can be culled and marketed as fat lambs at slaughter lamb prices. The subsequent high fertility and fecundity of ewe

EFFECTS OF BREED AND YEAR ON FERTILITY OF EWE LAMBS BRED IN NOVEMBER AND DECEMBER AT 7 TO 8 MONTHS OF AGE

	Percent pregnant (No. exposed)			
Breed	1970	1971	1972	1973
Rambouillet	17(18)	4(27)	16(38)	37(30)
Targhee	52(27)	10(31)	57(35)	73(37)
Dorset	92(26)	35(20)	64(39)	86(42)
Finnsheep	100(66)	92(39)	94(32)	87(31)
Polypay	100(6)	77(35)	94(65)	97(33)

Source: Hulet and Price (1975).

lambs selected in this way suggests that much of the lower fertility common to groups of sheep can be eliminated by selection at lamb age when market value is high. This type of management results in increased production efficiency of mature ewes selected at this time as compared with unselected ewes bred to lamb first as 2-year-olds (see next table.

Fertility in ewe lambs is reduced when they are mated in large flocks with mature ewes (Keane, 1976). This is because ewe lambs are shy breeders and are not competitive with mature ewes in seeking out the ram, nor do they stand well for mating. Therefore, ewe lambs should be bred separately from mature ewes. Experience of Ercanbrack at Dubois (personal communication) also suggests that yearling rams used on ewe lambs will increase percent of ewes lambing over inexperienced ram lambs.

INCREASING FERTILITY AND PROLIFICACY

Lambing rate is probably the most important single factor which can affect production efficiency in sheep. Fortunately, it is now possible, with existing genotypes of sheep already in this country, to select a breed or breed cross that will lamb at a rate which is optimum for each production environment. Strains of Merinos and Rambouillets are available which characteristically produce single lambs. Finnsheep, Romanovs and Boroola Merinos characteristically produce 3 to 5 lambs per lambing. Other breeds and crosses can be identified which produce lambs at various rates intermediate between these extremes. One of the most important management decisions is to select a breed that is adapted to the environment in question and continue to select for increased lambing rate within that breed and environment.

It may be possible in the future if FDA clearance is obtained to use a vaccine type product known as Fecundin to increase (0.20 -0.30%) the lambing rate of existing genotypes (Quirke et al. 1986; Croker et al., 1987).

Other important factors also affect fertility and prolificacy. These include age of ewe and season of year (next two tables), distance from the equator (increases with distance from equator), fertility of the ram, ambient temperature, nutrition, heterosis, disease and parasites. At one time, the ram was thought to have no influence on the fecundity of ewes to which he was mated. However, a study

LAMB PRODUCTION OF TARGHEE RANGE EWES BRED AND SELECTED ON PREGNANCY AT ONE YEAR OF AGE AS COMPARED TO EWES LAMBING FOR THE FIRST TIME AS 2-YEAR OLDS

Management Practice	Age of ewes, yr	No. of ewes	% of ewes lambed	% of lambs born[a]	% of lambs weaned[a]	Total lamb weaned, lb
Lambed first as 1 year old	1	47	100[b]	111	83	55
	2	47	98	143	115	84
	3 & over	78	97	158	134	107
Lambed first as 2 year olds	1	0	0	0	0	0
	2	50	88	102	82	58
	3 & over	65	89	141	115	87

[a] Percentage of lambs born or weaned of ewes in the flock.
[b] Only those ewe lambs diagnosed pregnant were saved.
Source: Hulet (1977).

EFFECT OF AGE OF DAM ON THREE LAMB PRODUCTION TRAITS

		FERTILITY	PROLIFICACY	OVERALL REPRODUCTION
Age of dam	No. of ewes bred	% of ewes lambing of ewes bred	% of lambs born of ewes lambing	% of lambs weaned of ewes bred
2	732	87	126	83
3	647	91	131	98
4	515	93	137	112
5	427	92	143	105
6	288	90	145	110
7	190	94	141	105
8	109	90	145	93
9+	54	82	153	99

Source: Sidwell et al.(1962).

EFFECT OF TIME OF BREEDING ON ESTRUS AND OVULATION IN MATURE RAMBOUILLET EWES IN IDAHO AND TEXAS

Month	Percent ewes in estrus		Percent ewes ovulating	
	Idaho	Texas	Idaho	Texas
January	100[a]	100	100	100
February	100	100	100	94
March	89	40	94	52
April	26	38	32	32
May	2	31	2	31
June	7	44	7	75
July	6	94	6	94
August	12	86	41	100
September	88	94	100	94
October	100	94	94	100
November	100	97	100	91
December	100	100	100	100

[a] Source: Hulet et al.(1974). Each statistic based 30 to 32 observations.

at Dubois (Hulet et al., 1965) clearly shows that rams with high quality semen fertilize a higher percentage of ova within ewes as well as a higher proportion of ewes than rams with low quality semen.

The last table above (Hulet et al., 1974a) also illustrates the effect of season on the occurrence of estrus, and on ovulation rate, which are closely correlated in most instances with lambing rate. Breeding season varies greatly with geographic area, therefore, the implications of breeding season and ovulation rate must be determined in each area. Because nutrition can have an important effect on lamb production, the common practice is to flush ewes just before and during breeding. Research (Hulet et al., 1974b) has shown that the time of year determines the effectiveness of flushing. Flushing during the middle of the breeding season does not appear to be beneficial, but flushing during the early and, especially, the late-season appears to be effective in stimulating higher ovulation rates. Scientists at Montana State University (Van Horn and Payne, 1951) have shown that supplementation of ewes on the range after breeding resulted in significantly higher lambing rates, presumably because of better embryo survival.

Poor sanitation can lead to severe losses from vibriosis, enzootic abortion of ewes and lamb scours. Reach-through feeders and clean water are vital to good reproduction in ewes kept in confinement. Vaccines are now available to protect against these problems, but should not be used as a substitute for good management and sanitation practices.

Early accurate information on the pregnancy status of a ewe opens many management opportunities for the producer. Real time B-mode ultrasonic imaging is an accurate pregnancy testing technique now available to the

sheep producer (Fowler and Wilkins, 1982; Fowler and Wilkins, 1980; Gearhart et al., 1988). It can reduce maintenance cost and increase production efficiency by identifying ewe lambs that are pregnant following breeding so that non-pregnant lambs can be marketed profitably as fat lambs. It can also be a real management benefit in identifying out-of-season bred ewes so that the open ewes can be removed to maintenance diets while the pregnant ewes are managed for lambing. Accuracy now is sufficiently high that it is practical to separate ewes carrying multiple fetuses for preferential feeding and more intensive lambing management while the single bearing ewes are kept at a lower and more economical nutritional and management level. However, because selection opportunities are low, an economical benefit from pregnancy testing high fertility, prolific flocks of mature ewes is unlikely. However, the ewe flock could be examined for visual evidence of pregnancy at the start of lambing. All ewes that do not show positive evidence of pregnancy can be separated using a cutting gate and then these few ewes tested for pregnancy. Any open ewes can be removed from the lambing flock and put on a maintenance diet.

Real time ultrasonic scanners are very expensive. However, an arrangement permitting a large group of sheep owners to use an instrument cooperatively, perhaps using the expertise of a county extension agent, could make it economical. A blood test based on a pregnancy specific protein shows promise of becoming an accurate, efficient, inexpensive pregnancy testing device that may also predict multiple births (Ruder-Montgomery et al. 1988).

RAM MANAGEMENT

Ram fertility is as critically important to lamb production efficiency as ewe fertility. Hot humid weather is especially detrimental to ram fertility. Behavior studies (Hulet, 1966) have shown that in the first 24 hours after a ram is put into breeding that he is nearly twice as active as later in the period. If introduction coincides with hot weather and the ram is introduced to the ewes in mid-morning, he may be sterile by evening due to elevated testicular temperature from a combination of physical exertion and ambient temperature. There are several safeguards to help protect rams from high temperature sterility: (1) provide pre-breeding conditioning exercise, if possible, (2) keep in strong condition but not fat, (3) shear three to six weeks before breeding (Hulet et al., 1956), (4) introduce to the flock in the evening after temperatures are dropping, (5) provide cool water and shade, (6) keep the number of ewes per ram relatively low (<50), (7) check testes repeatedly at frequent intervals (15 - 30 days) before breeding and use only rams with satisfactory breeding soundness examinations (Ruttle and Southward, 1988). This includes only rams with satisfactory semen quality (including freedom from leucocytes) with firm large testes ($\geq$30cm) free of palpable lesions. Testes size increases with age so selection on testes size should be made within age.

A knowledge of mating behavior in rams can improve production efficiency. A small percentage of rams have either greatly reduced libido (sex drive) or will not breed at all (Hulet et al., 1964). Other rams are aggressive and dominant, and in multi-sire mating flocks, will prevent or greatly reduce mating by subordinate rams. Therefore, it is important to make sure when rams are put into breeding that they have adequate libido and mating ability. It has been proposed that inhibition might be an effect of monosexual group rearing (Hulet et al., 1964; Mattner et al., 1971). Sexual inhibition was prevented by rearing ram lambs in isolation from other rams (Zenchak and Anderson, 1980). Keeping a few ewes with ram lambs during rearing may also reduce sexual inhibition in rams. In multi-sire breeding flocks, it is important to use a minimum of three

rams of uniform age in pastures large enough so that the dominant ram cannot prevent the other rams from breeding (Hulet, 1966).

EXTENDED BREEDING SEASON

Domestic sheep in general breed during a somewhat restricted season, mainly during late summer, autumn and early winter in temperate zones. Some breeds such as the Dorset, Rambouillet and Polypay have extended breeding seasons in contrast to breed such as the Suffolk, Southdown and Border Leicester. In the tropics and sub-tropics where variation in day length is minimal, sexual activity continues throughout the year (Hafez, 1953).

The seasonal nature of reproduction in sheep limits the times available to management for producing lamb for market, resulting in an uneven cyclic supply and market price of lamb. It also limits use of certain commercial and by-product feeds to times when lambs can be produced, which may not coincide with the most economical utilization of the feed.

Scientists are now using genetic selection to overcome this problem. This is a slow process and will require a number of years of research. The Polypay breed, as well as the Dorset and Rambouillet, is showing real promise in this area. Polypays are also highly prolific. Some immediate benefit can also be derived by manipulating behavior. Exposing rams to ewes in advance of the breeding season stimulates testes development and sex drive, and improves semen quality in rams (Illius et al.,1976). When rams are introduced into a flock (which has been isolated from rams for a few weeks) during the transitional period between anestrus and the breeding season, it leads to ovulation, followed by estrus and ovulation in advance of the normal breeding season (Martin and Scaramuzzi, 1983). The ram effect is probably augmented by social facilitation through the exhibition of estrus in responsive ewes, which in turn triggers estrus and ovulation in additional ewes. This early breeding response is maximized when rams are introduced in the morning (Martin et al., 1985). Manipulation of breeding behavior, especially in long-breeding season sheep, can produce fall lambs. A short-day light treatment (8 hour light, 16 hour dark) alone (Schanbacher, 1979) or in combination with melatonin implants (Regulin) six weeks before breeding can improve ram fertility and libido during seasonal anestrus (Fitzgerald et al., 1988).

Sixty to 80% of Rambouillet and Polypay ewes bred at the Jornada Experimental Range in New Mexico during May and June lamb in the fall. All the ewes are exposed again in September and October in a catch-up breeding so that any open ewes have an opportunity to breed and lamb in the spring. This gives a good supply of market lambs throughout most of the year. Ewe lambs and yearling ewes do not breed well out-of-season, and ovulation and twinning rate are lower in fall-lambing ewes (about 150% vs. 175% in spring averaged over breeds). Polypay ewes have a high percentage of twins in the fall (170% in fall vs. 205% in spring at Dubois).

ACCELERATED LAMBING SYSTEMS

Successful accelerated lambing systems usually require higher resource and management inputs than once per year lambing. Accelerated lambing should be considered under those conditions where a producer can provide adequate nutrition for the ewe and lamb. Accelerated systems are not recommended for extensive range conditions lacking the necessary feed resources and management options.

The economics of an accelerated lambing program need to be carefully studied. Increased income from extra lambs must pay for the extra cost and adequately compensate the producer for the extra labor input. Some systems for accelerated lambing are described below:

Three Lamb Crops in Two Years

Several variations of this system have been tried in order to attempt an average lambing interval of eight months, or a lambing frequency of 1.5 lambings per ewe per year. These systems have generally been characterized by a fixed mating and lambing schedule such as: May mating/October lambing, January mating/June lambing, September mating/-February lambing. Others have modified these dates slightly to 7-7-10 or 7-8-9 month intervals to better fit their climatic, management and feed resources. If a ewe misses once in two years, her potential is one lambing per year.

Producers have developed a variation of this system that provides for a more continuous lambing schedule. The flock is divided into four groups on a staggered eight-month lambing interval schedule. If a ewe fails to conceive with her group, she has a second chance to mate two months later, or on a ten-month lambing interval. A ewe that missed only one mating period in three cycles (two years) would average 1.39 lambings per year, and 1.29 lambings per year if she failed to conceive during two mating periods.

Research results have varied from a 10 to 15% increase in percentage lamb crop marketed per ewe with Hampshire x Rambouillet and Suffolk x Rambouillet ewes in Virginia, to a 43.5% increase in lamb production with Rambouillet ewes in Texas.

Researchers at Oklahoma State University reported results from studies involving various combinations of the Dorset, Finnsheep and Rambouillet breeds in which all breed groups averaged over two lambs born per ewe per year. These results represented a 30 to 35 percent increase over conventional annual lambings. Scientists at Purdue University reported that Rambouillet ewes performed better than Columbia ewes on the accelerated schedule.

Producers using the staggered two-month interval schedule have reported up to 40% increase in lamb production over previous conventional systems. They also suggested that, by dividing the flock into four groups, substantial savings in facility costs are possible. Increased management attention can be given to critical lambing and early lactation periods since all ewes are not lambing at the same time.

Five Lamb Crops in Three Years

In this system, developed by Cornell University and often called the Star system, the calendar year is divided into five segments (the points of the star) that each represent one-fifth of a year, or 73 days. The star can be rotated to give the most suitable dates. Two-fifths of a year is 146 days, which is approximately the gestation length of a ewe. The flock can be divided into three groups in this system. When the system is in operation, during the first 30 days of each segment one group lambs at the same time another group is being bred. The next 35 days in each segment would represent lactation for one group, late gestation for the second group, and early gestation for the third group. The second and third groups can be managed together, thus reducing the system to two groups. Lambs from the lactating ewes would be weaned seven to eight days before beginning the next breeding/lambing period. Ewes bred at the first period or point of the star would lamb 146 days later at the third point and could mate 73 days later at the fourth point to lamb 146 days later at the first point in the next year.

This system produces five lamb crops in three years, at a 7.2 month lambing interval. A ewe that did not miss a mating period in three years would lamb at each point of the star, and average 1.67 lambings per year. Missing one 73 day cycle in three years would result in an average of 1.56 lambings per year, while missing two cycles would result in 1.47 lambings per year.

Missing three cycles would reduce it to 1.33 lambings per year.

The Cornell University Dorset flock, which has been on some form of accelerated lambing for 15 years, averages approximately 1.5 lambings per ewe per year. The 1/2 Finnsheep x 1/2 Dorset ewes have had a longer lambing interval, with approximately 1.33 lambings per ewe per year, but this is more than overcome by the extra 0.5 lambs per lambing in the 1/2 Finnsheep ewes. More information is needed regarding expected lambing intervals and rates for sheep managed on this system.

Opportunistic Lambing

This system implies breeding for an extra lamb crop when conditions are desirable. These could be a favorable forage year because of adequate rainfall at the right time, or when lamb prices are unusually favorable, or for one last lamb crop before aged ewes are marketed for slaughter. These ewes can be pregnancy tested following breeding and only the pregnant ewes are retained for lambing. If it can be determined that there are several dry ewes in the flock, it may be desirable to breed before waiting for the next season. It is likely that some version of opportunistic lambing which is unique to the individual producer is the most widely used form of accelerated lambing.

Continuous Lambing

In this system rams are kept with the flock throughout the year. When ewes lamb, they may be removed from the flock for a week or two. Replacements are selected from lambs born during the least likely seasons from the most productive ewes. This system was used in the development of the Beltsville Morlam strain. Fifteen years of selection for the ability to lamb at any time of year indicated the effects of season on mating ability can be reduced by selection.

Two Lamb Crops Per Year

Scientists at Oklahoma State University using Dorset, Rambouillet, and Dorset x Rambouillet ewes reported that percentage lamb crop born was increased by 25% to 30% by lambing twice a year. The crossbred eyes performed better than either of the parent breeds.

Current studies on developing new breeds or lines of sheep that will lamb at six-month intervals are in progress at the Roman L. Hruska Meat Animal Research Center at Clay Center, Nebraska. In theory, this system would permit the maximum number of lambings per ewe, but it is unlikely this will be realized in practice. Even though this system is not recommended for commercial use at this time, it is hoped these important studies will result in production systems which approach twice per year lambing.

SELECTING THE BEST SYSTEM

Before selecting a specific mating and lambing system, one should consult with successful accelerated lamb producers in a geographic area that most nearly matches his own area. Determine how they do it and carefully study and evaluate economic and management advantages before launching into an accelerated program.

Other Factors to Consider

Types of accelerated lambing systems and the appropriate genetic resources for these systems are important determinants of success. Ewes must have the genetic potential for high prolificacy and frequent lambing and the system must permit optimum expression of these traits. Of equal importance are such factors as management capabilities, feed resources, facilities required for total or partial confinement systems and capital investment requirements. The individual producer must carefully consider all of these factors before starting an accelerated lambing program. As an example, more uniform distribution of labor require-

ments throughout the year may be considered an advantage to the person interested in specializing in sheep production. Yet it may be a disadvantage for the person having large investments in other enterprises that require high labor inputs at certain times of the year.

IMPROVED LAMB SURVIVAL AND PERFORMANCE

Reducing Losses in Postnatal Lambs

Often great disparity exists between lambs born and lambs reared. Most of this loss occurs during the first 30 days; the first 3 days are the most critical. Drs. Norman Gates at the U. S. Sheep Experiment Station, Dubois, Idaho (1977) and Joseph Rook at Michigan State University (1989) have conducted cause of death studies in baby lambs during their first 21 or 91 days of life. At Dubois, 66% of all losses could be attributed to starvation and lambs scours.

Recognizing the fact that many newborn lambs die from starvation because of chilling or insufficient milk production of the dam and that stress increases the incidence and severity of scours, the following procedure was implemented at the Dubois Sheep Station in 1976: (1) increase the number of individual lambing pens; (2) keep the lambs in pens longer (preferably 3 days, the time required for lambs to fully develop their thermoregulatory mechanism and an opportunity to observe for adequate nutrition; (3) provide more help to suckle lambs; (4) check all lambs in individual lambing pens and mixing pens for scours at least once each day and treat all sick lambs; (5) observe lambs carefully to see that they are getting enough milk and (6) graft hungry lambs to ewes having adequate milk (slime, wet, skin, stockinette and stanchion graft). Lamb losses during spring 1975 were compared with losses during spring 1976 lambings after the improved management input. Losses in 1975 were 12.6% of live lambs born; those in 1976 were only 4.1%, or an estimated net saving of $17,000 as an apparent product of the changed management practice.

In Michigan, the loss pattern was different. The largest losses were caused by dystocia/stillbirths followed by starvation/ hypothermia, pneumonia and abortions. Attention to the causes of loss by the producers brought about a decline in losses caused by starvation/hypothermia and pneumonia. These studies identify the importance of knowing the time and cause of lamb losses so that effective corrective action can be taken. A gross postmortem examination by a local veterinarian or experienced producer is probably the only economical way to arrive at a diagnosis of cause of death. A checklist for a postmortem examination is outlined by Rook (1989).

A lamb survival study in Texas under range conditions (Shelton and Willingham, 1989) showed that by shifting from a mid-winter to a mid-fall or early spring lambing season, lamb mortality was markedly reduced (41.9% and 15.8%, respectively). However, a reduction in conception rate and lambs born per ewe lambing, occurred in the fall, suggesting the need for extending the breeding season or having a catch-up breeding later on. Seasonal effects were minimal for single-born lambs but twin-born lambs had mortality rates of 29.9% for those born in mid-winter and 17.5% and 17.1% mortality rates for fall- and spring-born lambs, respectively.

Putting Lambs Where the Milk Is

Interest in artificial rearing of orphan lambs has increased with the advent of liquid milk replacer formulas. Very successful techniques have been developed both in labor-saving, self-feeding systems and in diets. However, costs remain high, and profits are often marginal.

The most economical way to raise lambs is on their dams. However, some ewes have more lambs than they can supply

adequate milk for, and other ewes have more milk than the lambs can use. Efficient management requires putting the lambs where there is adequate milk. This requires a procedure to graft or foster lambs with an inadequate supply of milk to a ewe with surplus milk. Procedures for doing this were outlined by Hulet et al. (1979). Lamb-specific odor is used by the ewe to distinguish their own lambs from other lambs. Lamb fostering techniques in general are designed to transfer sufficient odor to induce the ewe to claim and mother the orphan lamb. These techniques include slime grafting (transferring placenta fluids or birth slime to the orphan lamb), wet grafting (after newborn lamb is mostly dry, both "own" lamb and "extra" lamb are immersed in salt water and both lambs are thoroughly and systematically rubbed together), skin grafting (skin of ewe's dead lamb is put on the orphan; head, legs, and tail are smeared with blood and body fluids from the dead lamb), and cloth stockinettes (a stockinette is first placed on the ewe's own lamb as soon after birth as convenient. After about 24 hours, it is taken off the natural lamb and put on the orphan lamb [Price et al., 1984; Martin et al., 1987]).

Grafting or fostering is more successful when attempted as soon after parturition of the ewe as possible. This sensitive period varies greatly among ewes. The sensitive period can be extended with tranquilizers or with high doses of estrogen (Poindron et al., 1980). Some restraint of the ewe is often required for a highly successful fostering program (Alexander and Bradley, 1985).

SOCIAL BOND DISRUPTION AND STRESS

Stress, psychological and social factors influence the relative ease and efficiency of handling and working sheep, and can have profound effects on production efficiency. Weaning is an extreme example of the disruption of close social relationships. When lambs are early-weaned, they characteristically exhibit a stasis of growth. Nutritionists have tried without success to formulate diets which would eliminate this reduction in rate of growth. Stress associated with removing the lamb from its mother, a strange new environment and, frequently, a new type of feed probably account for the marked reduction in gain for a period of time following weaning. Lambs should be adapted to the feed they will be given at weaning starting at least a week before weaning, and the ewes should be moved away from the lambs and not the lambs away from the ewes. This permits the lambs to stay in familiar surroundings on a familiar feed which should reduce stress and improve post-weaning performance.

Disruption of social or companionship groups even later in life can be psychologically disturbing and can negatively affect performance for a period of time. If disruption of social groups occurs at breeding time, ovulation and fertility could be adversely affected, as has been observed in the human menstrual cycle. This may explain why some small farm flocks with one owner-operator have superior lamb production performance compared to large flocks where the sheep are sorted by various criteria into many small, single-sire breeding pens disrupting many close associations.

Sheep may also be stressed by inexperienced and abusive handlers. The consequence of the caretaker's attitude and behavior on livestock performance was demonstrated in a study evaluating operator attitude on milk production in dairy cattle. Production was better in cattle attended by a kindly, gentle person than one who disliked cattle (Seabrook, 1972).

MORE EFFICIENT UTILIZATION OF THE FORAGE RESOURCE

Research indicates that grazing more than one animal species on the same pasture contributes to more uniform and efficient utilization of the forage

resource (Cook, 1954; Bennett et al., 1970; Kautz and Van Dyne, 1978; Parker and Pope, 1983), providing a higher economic return (Hamilton and Bath, 1970; Terrill, 1975; Ospina, 1985). However, when this management is practiced, the cattle and sheep seldom graze together and sheep losses to predators may be too high.

We observed that cows normally protect their calves from coyotes as long as calves stay near their mothers. Would it be possible to socially bond young lambs to heifers so that the lambs would consistently stay with the cattle and would be protected from predation? We have since success- fully bonded 45- to 90-day old lambs to heifers by close confinement in groups of 7 lambs with 6 heifers or 7 lambs with 3 heifers for 60 days (Anderson et al., 1987). When turned to pasture, the bond needs to be solidified in small open pastures with one watering place. Lambs may become separated from the cattle while they are young, but normally get back together at the watering trough or while grazing. It is good during this developmental period to put them together whenever they are observed apart. Lambs that are bonded to cattle get good protection from predation (Hulet et al., 1987). We studied the defense mechanism using a trained Border Collie dog (Anderson et al., 1988). Bonded sheep always stayed close to cattle. Whenever the dog chased bonded sheep, they always ran to the middle of the cattle herd, leaving a perimeter of threatening cows. When the dog was urged, she was able to move the herd, but as they moved, the sheep stayed within the protective perimeter of cattle. At no time during many observations did the sheep separate from the cattle. In contrast, unbonded sheep, even when threatened by the dog, ran away from the cattle and thus were vulnerable to attack by predators. We observed a coyote approach a group of bonded lambs and heifers. One heifer chased the coyote out of the pasture. Mohair goats formed loose bonds with cattle, but did not stay with them consistently enough to get protection from predation. However, when mohair goats were also bonded to sheep that were bonded to cattle, they got good protection (Hulet et al., 1989). In contrast, Spanish goats appear to have as strong an affinity for cattle as for sheep.

Studies (Baxter, 1959; Bennett et al., 1970; Barger and Southcott, 1975) have also shown that multi-species grazing reduces the parasite load in cattle, sheep and goats. Rotational grazing not only maximizes forage production but it also reduces parasite problems.

PREDATOR CONTROL

Predation has been a very serious problem to sheep producers for many years. Coyotes have been singled out as major contributors to the decline of the sheep industry. Many individuals and rural families whose flocks and herds have suffered depredation have been forced to sell or to abandon operations (Senate Oversight Hearings Regarding Predators, 1980). Not only for the sheep operation to stay in business but to be profitable, a good predator control system appropriate to the particular farm or ranch environment must be in place. Electric fences can be very effective on open productive pastureland, but are not satisfactory in extensive range country especially where the terrain is rough and brushy. Guard dogs, when properly managed, are often more effective and reliable than most other systems in many situations (Green and Woodruff, 1983; Green and Woodruff, 1988). Donkeys and sheep bonded to cattle can be effective in some circumstances (Hulet al., 1987, 1989; Anderson et al., 1988) Hunting, denning, trapping, snaring and M-44 devices may be needed to supplement the basic guard protection system.

CONCLUSIONS AND FUTURE EXPECTATIONS

After years of frustration, a successful method has been devised for separating sperm carrying x and y chromosomes. Recently, females fertilized with the y-separated sperm

cells gave birth to 90% males; those fertilized with x-carrying sperm cells gave birth to 94% females (Johnson, 1989). Thus with the new and more sensitive sophisticated biological assays, computer analytical techniques, genetic engineering with its spin-off of cellular and subcellular manipulations, advances in immunocytochemistry, immunology, and immunotherapy, the relative explosion of synthetic biologicals all strongly suggest that we can expect great changes in the animal industries in the near future.

We are very close to the time when the majority of sheep will be bred to produce a first lamb crop of two lambs per ewe at one year of age. Strains of sheep will be available that will breed and produce twins at any season of the year and will be capable of producing more than one lamb crop per year. These lambs will gain faster on less feed than we now think possible. Furthermore, sex of the lamb will be decided at breeding time. Sheep will have a longer productive life and will be free of many of the diseases that reduce longevity and performance. The vision, courage, and untiring efforts of men like Dr. Clair E. Terrill have contributed and will continue to contribute much to the realization of these marvelous achievements.

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LAMBS AND WOOL

Maurice Shelton

The title, "Lambs and Wool", could be interpreted in many ways. The approach taken in this paper will be to comment on the current state of knowledge or state of the industry in respect to breeding for lamb and wool along with some speculation about what the future holds in respect to these products. Also, there seems to be some need to consider the question of lamb plus wool or lamb versus wool. In the writer's opinion, there is certainly some degree of competition for the nutrients required to produce these products at some time during the productive process, although there is some debate about this point among researchers.

THE RELATIVE ECONOMIC IMPORTANCE OF LAMB AND WOOL

Shown in figure 1 is the relative income from lamb (or meat) and wool under Texas conditions. The importance of the incentive program to the U.S. sheep industry can be seen when it is realized that numbers are, at best, stable under the present conditions with the incentive program in place. The termination of this program could not fail to have a negative impact on the industry.

Although variable from year to year, the relative income split between meat and wool under Texas conditions is approximately 70:30. New Mexico would be expected to be similar to Texas. Producers in other states would be expected to receive a smaller percent of their income from wool. This might range as low as zero for producers utilizing hair sheep (Blackbelly Barbado) or those who contribute the fleece as a part of the cost of shearing.

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The large share of income from meat occurred even though the percent lamb crop weaned is only on the order of 100 percent nationally, and lower for the range states, particularly the Southwest. The potential for increase in the lamb crop raised is quite good, with some individual producers weaning over 200% lamb crop. An improved lamb crop will increase total lamb sales, but will also improve production (nutritional) efficiency since feed consumed by the ewe is a major cost of production. If total lamb consumption remains static, or if serious price breaks continue to occur above a certain level of production, perhaps emphasis should be placed on improving efficiency through improved reproduction as contrasted to increasing numbers.

TRENDS IN LAMB PRODUCTION

The total amount of lamb meat produced and consumed in the U.S. has trended downward since the decade of the 1940s (Stillman, 1989), but this is largely the result of a decrease in total sheep numbers (10.8 million in 1989).

The lamb meat production in the U.S. expressed as a function of the number of breeding ewes available is high compared to other countries and has trended upward in recent decades. This implies that the U.S. producer is one of the more efficient lamb producers. However, closer scrutiny indicates that much of the apparent efficiency is related to the extensive use of feed lots or a high level of grain feeding. The upward trend in lamb production per ewe in recent decades is largely explained, or greatly influenced, by an increase in the weight of lambs at slaughter. This traces to an acceptance of larger lamb carcasses in market

channels and to the fact that feeders often find it advantageous to feed to heavy weights to the extent that carcasses will be accepted without serious discount. There has also been a consistent increase in the size of breeding stock, which has contributed to heavier slaughter weights (Parker and Pope, 1983). Higher slaughter weights tend to contribute to improvement in certain measures of efficiency, mainly those costs which are expressed on a per head basis, so long as the animals do not become overly fat for the intended market outlets. However, the major cost of lamb production is feed cost, and this may not be improved by increased size.

Two major factors which contribute to nutritional efficiency of lamb meat production are number of lambs reared per ewe and slaughter weight of the lamb relative to weight of the breeding ewe. The gain in efficiency associated with these variables is explained by the fact that the maintenance requirements of the ewe is expressed as a function of increased weight of lamb whether it is obtained from larger lambs or a larger number of lambs. Another factor which should be considered in looking at efficiency of lamb production is the amount or value of the wool produced. If wool income is adequate to recover a portion of the maintenance cost of the ewe, then the cost or efficiency of lamb production is altered and reproduction and slaughter weight become less important.

Shown in figure 2 are the trends in the lamb crop raised by regions of the U.S. Not surprisingly, these data show large differences in lamb crop by regions of the country. A second point of interest is that the lamb crop remained static for many years, and during this period of time the number of sheep in this country was on the decline. However, beginning around 1970, and more especially after 1975, the percent lamb crop raised has been on the increase in all regions except the Southwest. It can also be shown that the number, or more appropriately, the percent, of total U.S. sheep is being influenced by the lamb crop weaned. The percent of the total sheep numbers which are found in the Southwest has decreased over this period of time, whereas, by definition, the percent found in other regions has increased. This is especially true for some of the farm states of the East and Midwest. The important question is what has happened to bring about this improvement, and can it be accentuated or extended to other flocks or other regions? A number of possibilities might be suggested. These include:

(a) the use of more prolific breeds,
(b) increased use of crossbreeding,
(c) breeding ewe lambs,
(d) accelerated lambing,
(e) selection for increasing lambing rate, and
(f) increased use of artificial rearing or cross fostering of and other management practices with lambs, leading to improved lamb survival.

It is not possible to provide a definitive answer as to which of these reasons or other reasons provide the explanation for this upturn. However, in the writer's opinion, the timing of the introduction of the Finnsheep and the initiation of this upward trend is more than a coincidence, and that this provides the primary explanation for the upward trends in lamb crop raised. Finnsheep were first introduced by the USDA at Clay Center in the late 60's. Other introductions have occurred since that time. The availability and utilization of Finnsheep no doubt stimulated, or contributed to, a number of the other factors listed. For instance, they are utilized in commercial programs

Figure 1. Income to Texas Sheep Industry from Three Different Sources

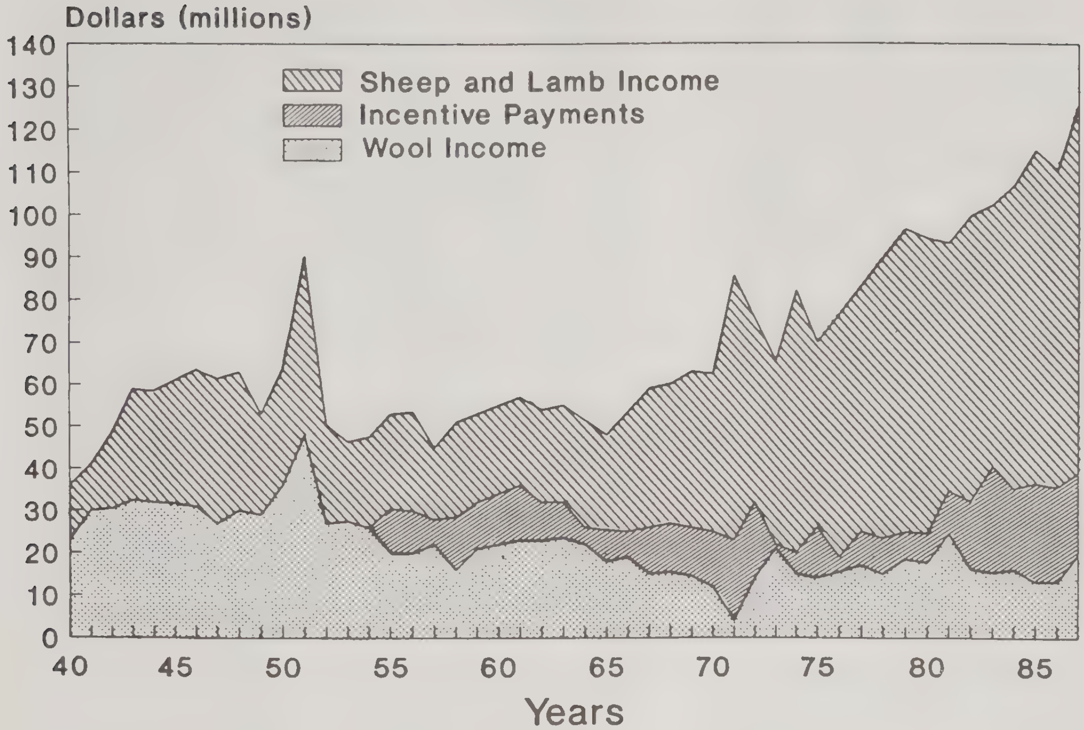
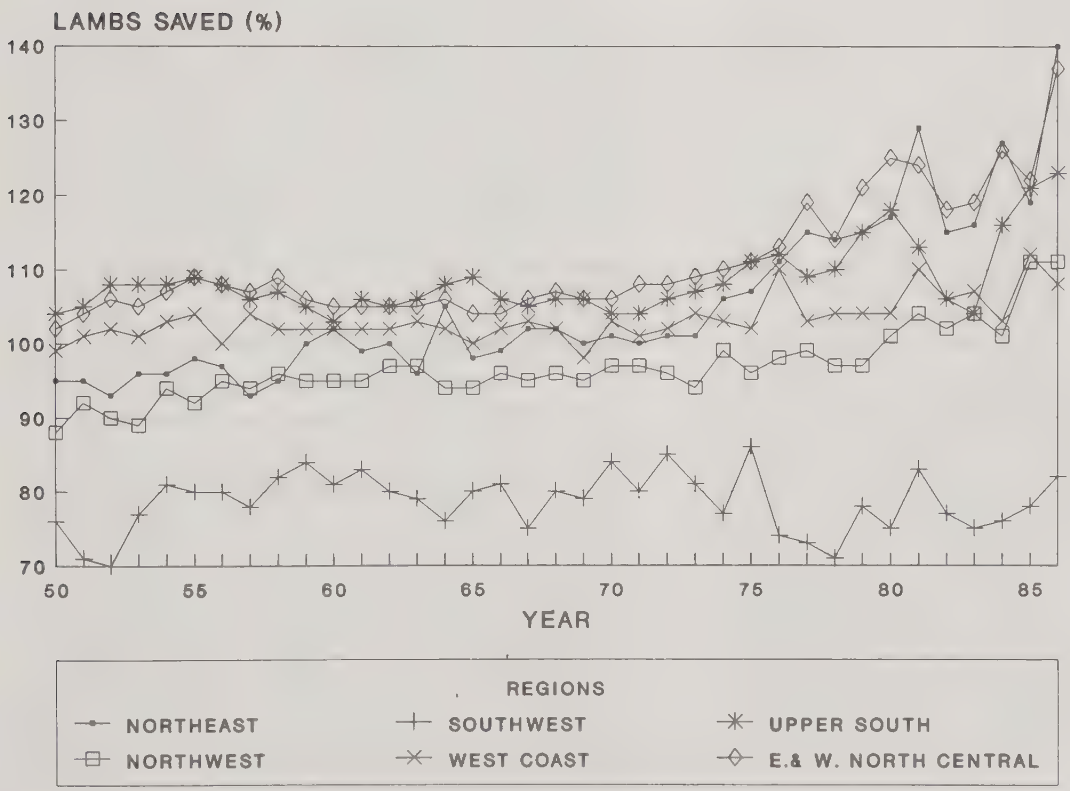


Figure 2. Lambs Saved as Percent of Ewes



only as crossbreds (F1 ewes) thus increasing the use of crossbreeding. These F1 crossbreds certainly contributed to increased use of the practice of breeding ewe lambs, since the practice of crossbreeding, especially with Finnsheep, improves the success rate of breeding ewe lambs. The potential offered by these more prolific types almost certainly stimulated increased interest in accelerated lambing, even though they may not be markedly more successful in breeding out of season than other breeds. The increased number of lambs from Finnsheep crosses almost certainly stimulated an interest in or a requirement for artificial rearing or cross fostering of lambs. This no doubt contributed to an increase in the total number of lambs raised even though the lamb mortality in percent may actually be higher for the more prolific breeds or crosses.

In the author's opinion, there is little evidence that selection within existing or traditional breeds for increased prolificacy has impacted the industry to the present time, although it certainly has the potential to do so. Finnsheep have not been used to any significant degree in the Southwest and there is no evidence (figure 2) of an improved lamb crop from this region. There can be several possible explanations for the failure to exploit the potential of Finnsheep in the Southwest. One of the most obvious of these is that production conditions of this region are less suitable for exploiting this resource (lack of adaptation) or for rearing the larger number of lambs produced. Another is that the fleece produced by part Finn sheep is lower in value than that of the traditional Finewool ewe (Snowder, Shelton and Thompson, 1985). Closely related to this is the fact that the increased income from wool in the Southwest, especially in recent years, makes it less imperative that high lamb crops are raised in order to stay in business.

Still, this Southwest region contained over 26.2 percent of the ewe flock in the U.S. in 1986. The percent of the ewe flock in the U.S. which is found in the Southwest region has been decreasing in recent years, and this may well continue unless wool prices attain and remain at a high level or unless the lamb crop from this region can be improved. The exploitation of more prolific types of sheep in the Southwest region is almost certainly more difficult than for most other regions or for some producers in other regions. However, research results and limited producer experience suggest that they can be utilized under some conditions. The use of the Booroola or the "F" gene is currently being explored. They do not possess the disadvantage of the lowered value of the fleece as with the Finn-cross. At this point it remains to be determined if the Booroola will have a major impact on the U.S. sheep industry.

The switch to utilization of more prolific breeds offers the greatest opportunity for an immediate impact on the industry. However, for a variety of reasons, a number of producers cannot, will not or in some cases should not, accept or utilize these types of sheep. For these, and perhaps all producers, it would be advantageous to improve lamb production of existing breeds which are in widespread use. For years, researchers have attempted to do this by nutrition or the use of hormones. Although nutrition certainly has an impact, it has not been possible to use nutrition to artificially stimulate reproduction. Also, there are currently no commercial programs in use in this country based on the use of hormones nor are the materials available on the market. Thus, it is currently believed that the genetic approach should hold primary interest in improving the potential lamb crop. Management programs may have a major impact on reducing reproductive wastage or improving lamb survival, and thus the realization of genetic

potential. Selection for lambing rate gives variable response and is greatly dependent on the numbers available and the selection intensity. Generally, the response has been in the range of 1 to 2 percent (lambs born) per year. However, significant progress on this difficult trait may require near single factor selection and few producers are willing to do this at present. Historically, the role of Experiment Stations has been to generate research information and leave breeding programs in the hands of producers. However, with the reduced size of the industry it may well be that it becomes more imperative that institutions undertake a more activist role in genetic improvement, particularly for difficult traits such as reproduction.

WOOL VS. LAMB

On a world basis, sheep are truly a multipurpose animal. However, in the U.S. they are viewed primarily as a dual purpose animal. Selection for increased lamb production is a relatively new approach, whereas, selection has been the primary means of improving wool production since the time that sheep were domesticated. Many producers or breeders have viewed themselves as selecting for lamb production, but for the most part they have emphasized size and conformation. Size does contribute, through growth rate, to increased per head production, but increased weight brought about in this manner makes little improvement in efficiency. This does not apply to sire breeds, where size and/or growth rate are of paramount importance. Larger size may contribute significantly to efficiency of red meat production or feed lot gains if animals are slaughtered at constant weights as contrasted to equivalent weights. Selection for lamb production should emphasize net reproductive rate and growth rate expressed as a function of size of the ewe maintained.

If one proposes to practice simultaneous selection for lamb and wool production, it is important to consider the phenotypic and genotypic correlation between these traits. Time and space will not permit a detailed literature review of this subject in this paper. Due to the environmental component, a phenotypic correlation between lamb and wool production would be expected. Somewhat contradictory to this is the observation that open or single rearing ewes will produce more wool than twin or triplet rearing ewes. This is a result of direct competition at a specific time. Although this is controversial, it is the writer's contention that there is a negative genetic relationship between lamb and wool production (see Turner, 1968; Shelton and Menzies, 1968; and Snowder and Shelton, 1988).

Other researchers have reported positive genetic correlations between body size and total pounds of lamb produced and fleece weight. This contradiction appears to have an explanation. If lamb weight weaned, expressed on a per head basis, is used in selection, body size will increase along with lamb weaning weights and fleece weight with the result that lamb and wool production appear to be correlated. Also, if fitness is a factor, the better adapted animal is likely to be larger and to produce more of both wool and lamb.

Across species or breeds within species there is a strong tendency for the smaller types to have a higher reproductive rate. If size remains constant or relatively constant and nutrition is a limiting factor throughout part of the year there will be a negative genetic relationship between reproductive rate and wool production. In the studies cited earlier the magnitude of the negative genetic correlations are low (on the order of 0.2). The appropriate interpretation of values of this magnitude is not clear, and

they can be overridden by selection. What should be evident is that when nutrition is a limiting factor, which is not an unusual occurrence, a ewe cannot use a given amount of nutrients for both reproduction and wool production. The nutrient requirement for ovulation is small, but it can be shown that a ewe in better condition, as a result of nutrition, does have a higher ovulation rate. The nutrients required for gestation and lactation are more substantial. It can be shown that the negative relationship between lamb and wool production is more related to lamb survival or growth than to ovulation rate or lambs dropped. Management interventions may be used to partially circumvent the conflict between lamb and wool production such as lamb survival. This would be accomplished largely through increased nutrition for those breeds with a heavier level of wool production.

OUTLOOK (LIMITATIONS TO LAMB PRODUCTION)

Total pounds of lamb produced and average per capita consumption in the U.S. have declined since approximately 1944. The relationship between these two variables is automatic, since all the lamb which is produced is consumed. However, with the low numbers of sheep in the country, slaughter (and slaughter capacity) and consumption have reached a low ebb. Increases in number of lambs slaughtered, substantially above 100,000 per week generates resistance at the market level and appears to place a cap on the size of the industry at present. As a result, lamb imports from Australia and New Zealand constitute a very real threat to the welfare of the U.S. sheep industry. Some possible approaches to alleviate this situation include (a) promotion to stimulate a greater demand, (b) producing more efficiently in order to make lamb available at a lower cost and thus stimulate a higher level of consumption, (c) improving lamb crops reared with a view to producing the required number of lambs from a smaller number of ewes and thus improving efficiency, (d) increasing the level and quality of wool production to reduce the reliance on lamb sales as a source of income. Some initiatives are underway in respect to each of these objectives, but progress on an industry-wide basis is slow. The most marked change has been in increased production per ewe and the potential to continue this trend is quite good. There is a real need for definitive research on the nutritional efficiency of fiber production to provide a guide as to how much emphasis should be placed on this trait in various production systems.

TRENDS IN WOOL PRODUCTION

Lupton (1989) reviewed the existing situation with the wool industry in the U.S. and Lupton and Shelton (1988) discussed implications of some of the recent developments to the producer. Wool production in the U.S. has dropped from approximately 450 million lbs. (grease basis) around 1940 to 86 millions lbs. in 1986. These two figures represent approximately 11.3% and 1.3% of the total world production, which in 1986 was approximately 6,560 million lbs. The U.S. consumers purchased 435 million clean lbs. in 1986. If clean yields are calculated at 55%, the U.S. produced less than 10% (9.56) of that consumed in this country. The reduction in U.S. wool production is largely explained by the decline in sheep numbers, but as pointed out by Lupton (1989), average fleece weights have declined as well and are below some of the primary wool producing countries. The decline in average fleece weights is usually explained by a preoccupation with lamb production. A shift in the sheep population to crossbred types utilized in the farm states, and a tendency to sell ewe lambs to slaughter and to keep ewes to older ages are likely the primary explanations. Total wool consumption in the U.S. has been on

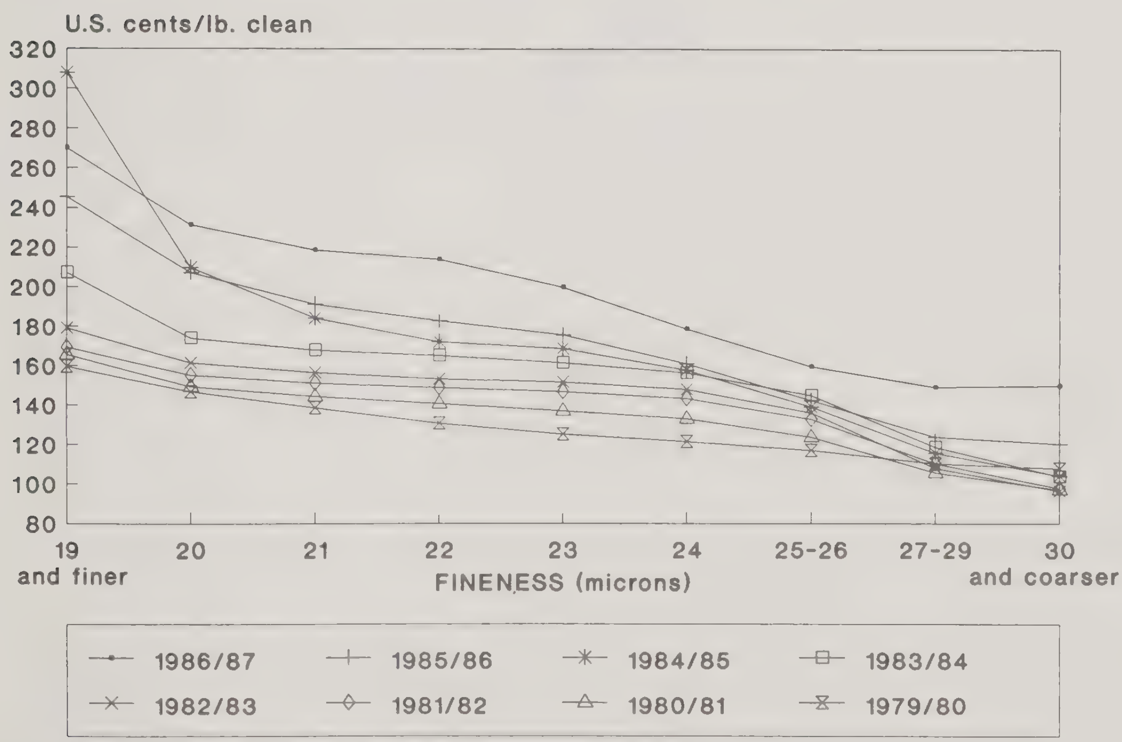
the increase since 1974 and thus a demand exists, although a large share of U.S. consumption is imported in the form of textiles. However, wool is traded on a world basis, and the U.S. producers must produce and sell on an international market. It is unlikely that U.S. producers can compete in this market unless wool continues to be secondary to lamb production. Within the U.S. the major wool producing states are Texas (19.58% of total), California (9.77%), Wyoming (8.67%), Colorado (7.19%) and Montana (6.48%). Six western states plus Texas produce approximately 60% of the U.S. total.

Wool prices have trended upward in recent years (with an all time high in 1988), but perhaps of greater significance, the premium paid for finer wools have increased in recent years (see figure 3, adapted from Lupton and Shelton, 1988). This can be shown to have had some impact on the industry with an increased demand for finewool rams (Rambouillet) in recent years. Also, Australian Merino rams, or semen from them, are currently being offered in this country. An extensive and multi-state research project is underway to evaluate the potential impact of the Australian Merino on the U.S. sheep flock.

SELECTING FOR WOOL PRODUCTION

The characteristics contributing to value in the wool clip for worsted processing are shown in table 1 (adapted from Lupton and Shelton, 1988). Essentially all the fleece traits, except for some obvious cases such as vegetable matter and strength or position of breaks, are highly inherited. Thus, selection for wool traits is reasonably easy. They are not only highly heritable, but they are expressed in the young male and are easily viewed and measured. Even

FIGURE 3. AVERAGE SELLING PRICE VERSUS FINENESS FOR AUSTRALIAN "FIRST HAND" WOOLS SOLD THROUGH AUCTION SYSTEM



though selection is easily accomplished, there are problems. One of these is that time is required to change populations, and it may be necessary to change breeds (to Merino types) in order to obtain an early response. Also, an early response may require near total emphasis on fleece traits, which few producers are willing to do. Fortunately, several of the characteristics of the fleece (weight, yield, length, etc.) are positively correlated. Fiber diameter is an exception. Since fiber diameter is a component of weight, it is difficult to emphasize a reduction in fiber diameter without some loss in fleece weight. Australian scientists and producers also believe that selection for fineness will result in some reduction in size of the animal, but U.S. experience does not necessarily support this position. Another point in question is the importance of and potential for selection for uniformity within the fleece. At least one major source of variation is attributable to the coarse britch. Shelton and Lewis (1986) and Willingham, Shelton and Bassett (1984) suggest that this trait may not warrant great emphasis in a selection program, even for finewool sheep.

Selection for wool production should emphasize fleece weight (preferably clean), fiber diameter and staple length (up to a point). Other traits such as color and coarse or hairy britch may be left for independent culling levels. Staple length is of critical importance only until all the animals in the population are producing staple wool. Grease weight and clean weight are highly correlated and grease weight may be safely used except for selecting stud rams or in populations with a lot of variability in oil content of the fleece. Other traits such as uniformity of diameter, crimp and handle or feel are comparatively less important and may be left as culling levels to remove "off-types".

TABLE 1. SIGNIFICANCE OF RAW WOOL CHARACTERISTICS TO VALUE IN RESPECT TO WORSTED PROCESSING

RAW WOOL CHARACTERISTICS	RELATIVE IMPORTANCE
Weight of fleece	****
Yield	****
Fiber diameter	****
Vegetable matter	***
Length	***
Strength/position of break	***
Color	***
Colored fibers	***
Fiber diameter variability	**
Length variability	**
Cotted fleeces	**
Crimp/resistance to compression	**
Staple tip	*
Age/breed/category	*
Style/character/handle	*

Key: **** Most important
*** Major
** Secondary
* Minor
Source: Adapted from Lupton and Shelton (1988)

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BIOTECHNICAL SELECTION

Clair E. Terrill

ABSTRACT

Biotechnical selection involves the simultaneous combination of a variety of technologies to obtain maximum progress toward increasing efficiency of lamb and wool production by selection. Selection is really immediate genetic engineering with proven success, and is much more promising than gene transfer. Selection for improved efficiency offers hope that full-time farmers will be able to obtain adequate net income to obtain a high standard of living. Sheep not only compare well with other farm crops in efficiency now but the practical ceiling for efficiency of lamb production is far higher and later in the future than for other farm crops so that efficiency can be increased over many more years than for other crops. Genetic improvement in sheep production efficiency depends on rapid selection for favorable combinations of multiple genes which increase the number and weight of offspring produced per ewe along with a reduction in feed and other costs. Selection for number of offspring, increased growth rates, reduced mortality, increased milk production and reduced feed costs must be applied simultaneously, not by a prescribed index but rather with emphasis on a single end point. Performance recording, embryo transfer, nuclear transfer, and selection for feed efficiency, year around lambing every 7.2 months, success of AI with frozen semen, meat quality and flavor, disease and parasite resistance and udders with 4 quarters and teats may all be combined to give maximum progress in overall merit and efficiency in research nucleus flocks with genetic progress passed on to the industry by sale of rams and semen.

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INTRODUCTION

Biotechnology is the science of combining technologies, especially genetic and reproductive, to achieve progress in productive efficiency that is generally not practical or effective when technologies are applied individually or in sequence. Practical gains in efficiency from nutrition and management have generally already been made so that further gains in efficiency, especially for ruminants, can probably be obtained by increasing the reproductive and growth rates, while at the same time improving product quality and reducing mortality and feed costs, all by genetic selection. Rapid selection as described by Encanbrack et al., 1989 presents a basic selection procedure to obtain genetic progress in efficiency much more quickly than ever before. Some of the increased progress comes from focusing on an overall measure of efficiency as the selection goal and some comes from reducing the generation length as shown by Dickerson and Hazel, 1944. Now by incorporating rapid selection into biotechnical selection, much further progress in efficiency can be obtained more certainly and quickly than by any other means including transgenic attempts.

Biotechnology is often thought of as transfer of individual genes or portions of chromosomes from one animal or species to another. To do this either by design or even somewhat at random requires so much time in years and knowledge that any important gain in efficiency will likely be sometime far in the distant future. Transgenic research should be continued but it should not be given priority over selection research. Even if individual

genes, having a strong effect on a specific aspect of reproduction or growth could be transferred, their effect might be more disruptive than advantageous. For example, the advantage in ovulation rate from the Booroola gene in merinos is often offset by lack of synchronization with mortality and lactation so that efficiency may actually decrease. Rexroad, 1986 outlines the requirements for using gene insertion in farm animals but concludes that predictions about the development of useful livestock are difficult to make. Rexroad, 1989 suggests that improved regulation of growth hormone, hormone transgenes or the use of other growth promoting genes will need to be studied before the transgenic approach for improved production efficiency of ruminants becomes practical.

The farm problem of low income and high expenses has resulted from a transfer of income from farmers producing food to non-farmers working in the food chain and to consumers, brought about by the marketing system (Terrill, 1988). This is resulting in a suppression of food production and a further reduction in the number of full-time farmers until government support returns an adequate standard of living to farmers. Meat and animal products are the most likely foods to be reduced, but meat and animal products are the ideal foods because they contain all of the nutrients essential to life. Research proposed here will certainly increase the efficiency of meat and fiber production. Small ruminants will likely enjoy the most rapid increase in efficiency because they can produce high quality food and fiber on forage alone, because they can utilize poor feed and poor land better than cattle or other farm animals and also utilize land which generally cannot be cultivated. Their early age of puberty, short reproductive cycle and high reproductive rate fits them for effective use of biotechnical selection to greatly increase efficiency and net returns.

Most major food and feed crops including beef cattle, and poultry are nearing their natural limits in efficiency. Small ruminants, alone, have very high limits on efficiency which will not be approached for many years. Biotechnical selection research on experiment stations shows the greatest promise for achieving these further increases. Transferring this technology to breeders and producers by sale of rams from experiment stations has proven to be effective. Increasing efficiency of sheep production on farms from biotechnical research on experiment stations gives promise, in time, of providing a high standard of living for farm families.

Increasing Sheep Efficiency

Genetic improvement in efficiency depends on selection for favorable combinations of multiple genes which increase the number and weight of offspring weaned or marketed plus fleece weight per ewe along with a reduction in ever increasing costs. Thus, increased number of offspring per ewe, reduced mortality, increased milk production, increased growth rate and fleece weight and reduced feed costs must all go together. This explains why selection for an overall endpoint, such as weight of lambs weaned or marketed plus fleece weight per ewe is probably much more effective than an index which involves prescribed emphasis on each individual trait. Thus, the genetic makeup of ewes is gradually changed to improve all aspects of reproduction and growth simultaneously. Then, the number of adults is reduced according to the increase in number of offspring so that total feed and other costs are reduced or held constant.

Traditional sheep production research, made available through publication in scientific journals, appears to be ineffective toward increasing sheep efficiency because maximum practical gains in efficiency from this type of research have already been made (Terrill, 1989a). Neither is competitive grant research likely to be effective because it tends to be short time and often involves a single discipline while efficiency increasing research must now be multidiscipline and long time, team

research. The cumulative gains from many small bits of research is no longer effective in agricultural as it is in medical research. Terrill (1989a) has shown that maximum gains in efficiency in the sheep industry came from long time selection research with the gains passed to breeders and producers by sale of rams from the research station. Furthermore, these results indicate that modern selection gains and especially biotechnical selection gains will need to be made on research stations and then passed to breeders and producers through the sale of rams or semen. Gains in efficiency in the industry from selection research are made not only more quickly than from traditional research, but every year, without the long time lag that formerly occurred between the time of publication of the research and its full application. Gains from traditional agricultural research are still feasible but such should be planned to supplement or complement biotechnical selection, rather than instead of such research. Biotechnical selection should not involve a routine procedure but rather should follow the lead of Ercanbrack et al. (1989) in attempting to increase the rate of progress each year.

Research to increase efficiency through biotechnical selection should be paid for by the public because it is the public that benefits. Since the cost price squeeze on farmers has intensified in the 1980's the incomes to workers in the food chain appear to have increased while farm income has decreased. Also the cost of food to the consumer in relation to income is now less in the United States than anywhere else in the world. Food is as much as two to three times as expensive in Europe as in the United States, but Europe is maintaining its full-time farm producers and the United States is not. Income that should be going to farmers is now going to non-farm workers and consumers. Increased net farm income from the increased efficiency of small ruminants from biotechnical selection offers a partial solution to the problem and will also increase high quality food production from feed materials which people cannot eat.

Biotechnical selection can increase overall efficiency and at the same time improve quality of products to an extent not heretofore possible. Value added in production will be in addition to value added in processing and marketing. The possibility of producing a super lamb meat, with the ultimate in flavor, tenderness, and fat content for both domestic use and export will become real. Possibly the huge gap in price between the farmer and the consumer can be narrowed.

An important objective for increasing efficiency of sheep is to offset losses from predators. Predator losses have not only reduced net incomes but have caused a reduction in sheep farm operations from about 242,000 to 114,000 from 1965 to 1987. During the period from 1960 through 1987 a total of about 37 million sheep and lambs were killed by predators while the sheep inventory was reduced from 33 million in 1960 to 10 million in 1987. In the 28 year period the loss of sheep and lambs totals about 1.4 billion dollars in a 600 million dollar industry. This shows that the low per capita consumption of lamb in the 1980's is due to predator losses rather than low demand for lamb meat. In fact all through this 28 year period, lamb at retail was generally higher than retail beef, pork or poultry indicating that consumer demand for lamb has remained high. Increased efficiency of lamb production in the 10 northwestern states related to the purchase of improved rams from Dubois has more than offset predator losses while this is not true of the other 40 states (Terrill, 1989a).

An increase in economic efficiency from selection research at the U.S. Sheep Experiment Station, Dubois, ID, has been shown especially since the use of rapid selection at Dubois beginning in the 1970's (Terrill, 1985, 1987, and 1989). The objective of this selection research has been to increase the rate of progress from rapid selection rather than to determine progress obtained from a prescribed selection procedure. About 96% of the rams sold from Dubois went to

the ten northwest states. The improvement in sheep and lambs marketed per ewe in these northwest states paralleled the genetic improvement in the selected groups at Dubois as compared with unselected random mating control groups. Net incomes from sheep in the northwest states for the last 8 years totaled 130 million dollars as compared with a loss of 38 million dollars in the other states indicating the success of the selection research at Dubois in increasing economic efficiency in the industry.

SELECTION PROCEDURES

Performance Recording

Record keeping is essential to any selection procedure. With biotechnical selection all important records must be taken at weaning age because selection of rams will be on weanlings. Also weaning time is the only age at which records can be taken on the entire population of offspring. Even though selection is largely based on weight of lambs weaned per ewe and fleece weight records, other traits which are significant in production should be measured and monitored to detect any negative trends. Lambs should be sheared at about 6 months of age to obtain fleece weights which will provide the best estimate of fleece weight before weanling selections are made. Lambing records, fleece and body weights and possibly other records should be taken at least annually on all sheep kept beyond weaning age.

Foundation Stock

Four or more different breed groups, each with about 225 ewes, one year old or older, should be mated at each ecosystem location. Not more than one breed should be duplicated at adjacent locations. The best adapted and best established breeds in each ecosystem area should be favored along with one or two new breeds or breed crosses, generally containing high fertility breeding.

Superior foundation rams and ewes, registered if from pure breeds, should be obtained from a variety of sources within each ecosystem areas if feasible. High reproductive rates at a young age along with rapid growth rates of offspring as well as heavy fleece weights should be emphasized. Twins raised as twins from young mothers should be highly favored, at least five relatively unrelated sires should be used initially within each breed group with subsequent maintenance of 3 to 5 sire lives, and ewes to be rotated among less related sire lines. Each breed group will generally be closed to outside breeding although some outside blood might be introduced in the first few years. At least one random selected, random mating control group from one breed should be maintained at each location.

Embryo Transfer

Embryo transfer has been proposed to increase the selection differential and to reduce the generation length for female sheep although further research and development and the development of special nucleus selection stocks would be needed (Smith, 1986 and 1988). This might result in a doubling of genetic progress for individual traits although a somewhat lesser gain might be expected. Similar gains in growth and carcass traits from terminal sires are predicted by Steane et al, 1988.

Embryo transfer should be used in biotechnical selection from the start along with research to increase the rate of progress and effectiveness. Use of super ovulation is questionable because it interferes with the normal ovulation rate which is so important a part of weight of lamb weaned per ewe mated. Possibly two parallel groups in the same breed and location might involve normal ovulation in one group and super ovulation in the other but any conclusions as to the comparison of the two methods should be postponed for 10 to 20 years.

Embryo transfer along with splitting of embryos to produce identical siblings for testing for carcass traits or disease or parasite resistance should be used from

the start along with nuclear transplantation or transfer (Seidel, 1989 and Prather and First, 1989). These techniques could with further research produce sufficient identicals for testing for resistance to a number of different diseases or parasites or other traits which would render the animal useless for breeding. The use of these techniques should begin immediately even though the success rate might be low because even a little increase in rate of progress would be worthwhile.

Nuclear Transfer

Embryos can be cloned by nuclear transplantation (Seidel, 1989). The 16 nuclei in a 16-cell embryo could be transplanted into 16 1-cell embryos in which the original genes have been destroyed. Even with low success a few identical offspring might be obtained so that one or more could be used in breeding and the others could be used for testing which requires the sacrifice of the individual. Prather and First, 1989 have used nuclear transfer to study the differentiation process in embryo genesis when nuclei are transferred to activated, enucleated oocytes the nuclei swell in diameter, synthesize DNA, acquire cytoplasmic proteins and release nuclear proteins. This protein exchange is thought to result in the transferred nucleus behaving as a zygotic nucleus. Research to develop, perfect and use this technology to produce multiple identicals will be an important part of biotechnical selection.

Feed Efficiency

In selecting for overall efficiency, feed efficiency should receive emphasis, possibly 20 percent because it tends to reduce feed costs even though much of the feed is harvested by the animal. Of course, weight of lamb weaned per ewe and fleece weight should always receive major emphasis, at least 60 percent because they represent most of the sale income. Improvement of feed efficiency may lead to direct gains in digestibility and assimilation of nutrients. It also leads to increased secretion of growth hormones (Dodson et al., 1982). The increased production of growth hormones from selection for rate of gain and feed efficiency probably will also lead to increased efficiency of milk and wool production.

The effectiveness of selection for postweaning rate of gain and feed efficiency and the details of measuring feed efficiency have been presented by Encanbrack, 1982 and Encanbrack and Knight, 1988. The essential elements include a 16 week feeding period beginning at about 80 days of age and with measured individual feed consumption during the second 6 week feeding period. At the end of a 4-year study the selected lambs were about 23% more efficient than the controls, meaning that they were producing about 23% more net income per day than the control lambs. Carcass studies showed that the higher efficiency and greater carcass weight of the more efficient lambs was achieved without increasing carcass fat percent. Somewhat slower progress would be expected if 3 times as much emphasis is given to weight of lambs weaned per ewe but no conflict between the two traits would be expected.

Selection for Year Around Lambing Every 7.2 Months

Lambing, beginning at 7.2 months and continuing every 7.2 months thereafter is the most practical and most efficient method of lamb production although seasonality of lamb production must be removed by selection and economical winter feed and housing must be available. Where sheep often migrate to different feeding areas, as in the Intermountain West, a 6 months lambing interval would be needed. Such is genetically feasible but not in near future as is lambing every 7.2 months. Such year-around production gives more regular lamb marketing and cash income throughout the year as well as a much greater yield of lambs per ewe. This is undoubtedly the system of lamb production for future full-time sheep farmers outside of the Intermountain West.

The STAR system, developed by Hogue and Magee, 1985 is the system of choice in selecting for lambing the year around. They have shown that it does not violate sheep biology, it fits the calendar year and it greatly simplifies management, by making breeding and lambing dates exactly coincide. The five lambing periods per year allows identification of ewes (and their sons) that not only will breed out of season but will breed and lamb in any season following lambing in any other season. It also allows an even annual production of market lambs for an even cash flow and uniform supply of lamb; increases efficiency of utilization of facilities as for lambing; and leads to a ewe lambing 5 times in 3 years which is a 67 percent increase in production over once a year lambing. Ewes are selected to lamb on their own at night so that labor can fit the standard 40 hour week although some overtime may be required on weekends during lambing and during the haying season. Daily observations are generally essential in any full-time sheep operation.

Selection for year around lambing consists of selecting sons, born at the most difficult time of the year, probably from August to November, from mothers with highest lamb production per year. Ewes which fail to lamb as lambs and/or after 2 breeding periods should be culled first. Later those that fail in one breeding period can be culled as numbers permit.

Success of AI with Frozen Semen

Artificial insemination (AI) is needed not for use in the research nucleus flocks, as natural breeding will be adequate there, but in spreading improved breeding to flocks in industry, especially to small producers who can probably not afford highly improved rams. Furthermore, sufficient rams for industry needs can probably not be supplied from research flocks so that AI will increase the use of the selected rams and those with the best records. Use of frozen semen will probably be essential for distribution of semen by mail. Vaginal insemination by farmers to synchronized ewes will be economically desirable. Therefore, the success rate of AI with frozen semen will probably need to be doubled by selection to insure its practical use.

Selection for success of AI has not been done to my knowledge but use of AI, generally with fresh semen has been used in Norway for many years for improvement of sheep production on farms (Steane, 1982; Olesen, 1988a). Olesen, 1988b has indicated that there is considerable variation in performance of individual rams by AI. This indicates that genetic variability is quite high as might be expected. Therefore, immediate selection for success of AI in research nucleus flocks seems highly desirable. Greyling and Grobbelaar, 1988 have described the process of AI. Synchronization of esturs and ovulation will probably be essential to use of AI (Hoppe and Slyter, 1989) and synchronization of parturition may be desirable (Rommereim and Slyter, 1981).

Selection for success of AI will involve screening of ram lambs, not only on semen quality after freezing but also on those who rank high on their mother's productivity and on rate of gain and feed efficiency. Then those that rank high in the screening test (at least 2 to 3 times as many as will be used in breeding) will be tested by insemination in test ewes followed by early pregnancy diagnosis. It is hoped that at least one ram, ranking high for success of AI, can be used in each breed group each year.

Meat Quality and Flavor

Lamb meat is generally high quality already, considering tenderness, flavor and leanness. However, there is preference for lamb with only a slight flavor and with a low fat content. Further selection is needed to insure that most lamb has a delicate, slight flavor which seems most desired. Research is needed on the chemical basis for flavor so that objective tests can be developed to be able to select super flavor lamb for gourmet restaurants and to be able to improve the flavor of

average lamb by selection. However, taste panel tests should be used for such selections until objective tests are available. Production of multiple identicals will make carcass tests feasible.

Overfat lambs are generally the result of extended feeding in feed lots and often by processing plants rather than farmers. Selection for optimum fat content regardless of age or weight seems desirable from a market standpoint because the American Public detests fat. There is probably no biological need for extra fat by sheep if ample feed is provided in winter and in times of drought. Simm and Steane expect high rates of progress from selection based on in vivo estimated carcass composition as early results from experiments are encouraging. They also mention that genetic improvement could be further enhanced by improved techniques of in vivo estimation of carcass composition and use of embryo transfer to increase selection intensity in females.

Disease and Parasite Resistance

Selection for disease and parasite resistance becomes much more feasible with multiple production of identicals for testing. Even though these diseases and parasite problems are now under reasonably good control, there is still need for improved resistance, especially for foot rot and internal parasites generally in warm, humid ecosystems.

Warwick et al., 1949 pioneered in selection for resistance to stomach worms, Haemorchus contortus in Rambomilliets. Survival without treatment was used as criteria for selection. In the last two of nine years survival rates were 64 and 85 percent respectively. Baker et al., 1988 using faecal egg counts in New Zealand sheep found useful genetic variation and response to selection for high and low counts. Charon and Skolasinski, 1988 found breed differences in mastitis rates in sheep. Cumlivski, 1988 found relatively high genetic resistance to foot rot of some British sheep breeds. Pepin et al., 1988 found some resistance to Caseous lymphadenitis in the Isle-de-France breed in comparison with two other French breeds.

Attention to selection for resistance to disease and parasites should be given in relation to their economic importance. Sufficient attention should be given to each to bring positive selection pressure even though greater pressure may not be justified.

Udders with 4 Quarters and Tests

Selection for larger udders with 4 quarters and teats in sheep seems justified now because selection for weight of lambs or number of lambs weaned per ewe lambing is resulting in an increasing number of triplets, quadruplets and high multiples being born each year. Many ewes are weaning triplets but there are difficulties that would be solved if the ewe had 4 equal quarters and teats, especially where quadruplets are born. Artificial rearing is generally quite practical but it is not an economical substitute for a lamb raised by a ewe. It seems clear now that the number of lambs weaned per ewe in the future will increase at least to 4.

Phillips et al., 1945 extended the selection of the Alexander Graham Bell flock for multinipples. Although they concluded that the multinipple character had no practical value this was before the time of the widespread use of high fertility breeds. Their results really showed the futility for selecting for one trait at a time. Now, with simultaneous selection pressure on number of lambs born and weaned and on milk production, the 4-teated 4-quarter udder becomes a necessary reality for future sheep.

Fortunately, a number of people in the world are now selecting for multiple nipples along with lamb and milk production. Davies, 1989 reports that there are more than 100 ewes, having longer extra teats which produce measurable amounts of milk. In several ewes the front teats produce 10 to 15 percent of total yield. Therefore, in

biotechnical selection there should be emphasis on developing 4 functional teats and udder quarters through selection along with lamb production and milk production so that eventually, improved ewes will be able to wean a total of 4 lambs of somewhat equal and acceptable weight.

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THE FUTURE OF SHEEP AND SHEEP RESEARCH: SUMMARY

T. W. Perry

An excellent review of the U.S. Sheep Industry was prepared by Charlie Parker and Art Pope for the Diamond Jubilee of the American Society of Animal Science in 1983. A part of that comprehensive review will be cited. Furthermore, the speakers which have preceded me on this seminar have made valuable contributions to the literature on the sheep industry.

In searching the literature for preparation of this talk, in the first two volumes of the Journal of Animal Science (1942 and 1943), surely enough, there were two research articles by our honored friend, Dr. Clair E. Terrill, namely:

1. "Clean Wool Yield Variation Among Regions of Rambouillet Fleeces" by Terrill and associates.

2. "Factors Affecting Blood Phosphorus Levels of Range Ewes" by Terrill and associates.

Indeed, Clair E. Terrill, "Mr. Sheepman", U.S.A. and World renowned sheep scientist, it is a pleasure to present some thoughts of my own as I interpret the sheep picture ahead.

Lamb Consumption in the U.S.A.

In this subject area, at first it was rather discouraging to set down the numbers for lamb consumption beside those for beef and pork. According to 1984 data presented by Breidenstein and Williams of the National Livestock and Meat Board, one-half of one percent of the total red meat consumed by the American public is lamb (Table 1).

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As indicated in the opening sentence of this section, the statement was made that the consumption of lamb per capita was indeed discouraging. However, upon further deliberation, one should not be too quick to condemn the American people for the low consumption of lamb. I'm not convinced the American people actually discard any lamb meat. In other words, we seem to consume all we eat and thus perhaps the real culprit in this equation is the lamb producer. For if we eat all the lamb we produce, then perhaps the science of increased lamb production is where most attention is needed for the present.

Sheep Numbers in the U.S. Have Declined

Except for a small glitch in the graph of sheep numbers for 1958 to 1960, sheep numbers in the U.S. have declined steadily since 1943 to 1979. Between 1954 and 1979, there was 63% decline in sheep numbers. The 1983 sheep population of 11.9 million represents only 21% of the number of sheep on farms in 1942.

Table 1. Average Daily Cooked Red Meat Ingestion in the U.S. Diet in 1984*

	Grams per day	Percent of Total red meat
Fresh beef	42.16	36
Ground beef	17.5	15
Fresh pork	11.17	9
Fresh lamb	.62	.5
Fresh veal	1.22	1
Processed meat	44.33	38
Total	117.00	99.5

*Breidenstein, B.C. and J.C. Williams. National Livestock and Meat Board, Chicago, Illinois 60611.

Even though sheep numbers in the U.S. have continued to decline so drastically, wool utilization continues to exceed domestic production by approximately 170%.

What has brought about the dramatic decline in sheep numbers? Is it totally economic? It is most difficult to answer these questions. Some would say the frustration of coping with predators plays a key role in the sheep numbers decline in the U.S. All of us are aware of the continued effort our honored guest has put into attempting to make regulatory people more aware of the threat of predators. Shelton and Wade[1/] (1979) reported that predatory losses are one of the most serious problems facing the Western range livestock industry. Such predators include the domestic dogs which belong to some of you people reading this. Thus, it is not only the wild animal predators which threaten the sheep industry. As of 1972, it is not possible to use poisonous chemicals on federal lands for predatory control. The annual loss of sheep and lambs to predators exceeds 1.1 million head[2/] (Gee and Madsen), and you can supply any dollar per head figure to that number which sounds reasonable to you. Our honored guest in 1981, at a conference on controlling predators, proposed that predation constituted the major cause for the decline in the sheep industry in recent years.

Although total sheep numbers have declined drastically, the same for registered purebred sheep has gone in the opposite direction. In the 21 years between 1960 and 1981, the total number of purebred registrations in some 20 organizations had increased over 50 percent.

Perhaps breeders have not paid enough attention to the selection of sheep for economic traits. More than 30 years ago our honored guest suggested in the Golden Anniversary Year (1958) issue of the Journal of Animal Science that more emphasis should be placed on production traits in selection. He even started the blueprint by pinpointing selection for early puberty, nonseasonality of breeding, fertility, and rates of lambing and rearing.

From this author's point of view, breeders have not listened to Dr. Terrill's plea. His sound teachings have fallen on deaf ears or else the connection between the ears and action on the part of sheep breeders has become unplugged. What did one have to do to win the grand championship at Chicago in the wether competition? Those champion sheep showmen can tell us! Select the shortest-legged, blockiest animal possible - doesn't make any difference how slowly the animal gained nor how tiny the carcass was. It is not my purpose to criticize any breed because if one selected sufficiently severely, probably almost anything that would win the show could be found in most breeds. However, we've all seen the decline and fall of several breeds of sheep which were perennial winners in the sheep show. Has this helped the sheep industry? It is doubtful. Perhaps we're looking as we change from one type of sheep to another. Wouldn't it be interesting to have a typical grand champion lamb from 1959 and the one that is champion here at the show this year?

I'm not sure we have included anything herein that explains the decline in sheep numbers in the U.S., and yet maybe a few of the causes have been included.

What Lies Ahead?

A scientist does not like to predict things - rather he prefers to make predictions based upon known and tested facts. Yet, in spite of that reluctance, each of us on the program was challenged to do a little predicting.

First of all, let's never forget sheep are undoubtedly the best foragers of humanly inedible products such as

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1/ Anim. Industry Today, Vol. 2, No. 1. Champaign, IL.

2/ Econ. Dept. Rept. EA-6. Colorado State Univ., Fort Collins.

cellulose products. At such time as humans took greater and greater proportions of the feed grains for human food, naturally the monogastric animals such as poultry and swine would fall by the wayside. But we should not get our hopes high too quickly on that note because our problem in grain production today is to hold down the excessive production of such commodities.

There are very strong competitors out there for the animal protein dollar. It must be borne in mind that if we are able to increase the per capita consumption of lamb, it will be at the expense of some other animal protein. It seems the American public will purchase the equivalent of only about 200 pounds of animal protein (wet basis) per year. In other words, we don't seem to be able to induce people to just add one meat additional. So, it's going to be tough to increase the annual consumption of lamb above the current one-half of one percent of total red meat consumption, unless we make it a more attractive buy somehow. It will require newer technologies in sheep production which make it both more economical and more attractive. Research will be required to achieve these goals. Ten years ago (1979) our honored guest told the National Wool Growers Magazine he estimated at least 90 percent of all sheep research was conducted <u>outside the U.S.A.</u>!

What needs researching in the sheep industry? Just about any facet of the industry one wants to name needs researching. Is our method of merchandising lamb carcass modern? No! Look what Kentucky Fried Chicken has done to the chicken carcass. I believe their technique gets about 9 pieces out of a chicken carcass - and it is all due to researching how best to get the job done.

In 1981, J. J. Robinson reviewed production technologies at the Rowett Institute and pointed out the annual production level achieved of 340 lambs per 100 breeding ewes represented a 100% increase in ewe productivity.

Higher lambing rates. A very small percentage of the commercial ewes consistently produce and wean multiple births. We need to reduce the seasonality and at the same time increase lambing rate.

In the area of disease, could we develop genetic resistance to several problems such as footrot and several others?

Will nutrition and/or genetics improve wool production? Probably. But that hypothesis needs to be researched and established.

Will automation enter into the picture of sheep production? Maybe one can develop labor-saving devices such as robot shearing and even herding. Maybe some type of robot to protect sheep from predators.

The future of the sheep industry in the U.S.A. depends largely on how much effort we're willing to expend on it. In other words, it will not just "happen". All of us are going to have to dedicate ourselves to "making it happen."

Portrait Presentation
of

Clair E. Terrill

at the

SADDLE & SIRLOIN

Banquet

CLAIR TERRILL; A REMARKABLE HUMAN BEING

David Richard Lincicome*

President Nicholas Murray Butler and Professor Brander Matthews of Columbia University were discussing plagiarism and the latter was giving his views from a paper of his own on the subject. He said, "In the case of the first man to use an anecdote, there is originality; in the case of the second, there is plagiarism; with the third, it is lack of originality; and with the fourth, it is drawing from a common stock." "Yes", said President Butler, "and in the case of the fifth, it is research" (Fadiman, 1985).

For that fifth man we are gathered together today to recognize and honor, research - that base upon which progress is built - rests heavily on his shoulders. Research to Clair Terrill is a passion, all-consuming to be sure, but pragmatic; and it must address efficiency.

Several years ago Art Hoversland, Clair Terrill and I began luncheon meetings as a result of our multifold common interests in goats and sheep. After several of these working lunches we became aware that all three of us frequently wore red ties to these meetings. From then on to the present, the "Red Tie Boys" gather for lunch, each wearing a red tie. Sometimes, when the red tie is omitted, the culprit is awarded 10 demerits. While perhaps some would label this as preppish or schoolboyish, the symbol of the "Red Tie" has nurtured an association and a cementing of professional/personal relationships rarely achieved. It has provided a unique forum to draw a portrait of a man wholly dedicated to the American Agricultural Community. Our Tuesday working lunches begin at 1130 hours at the Naval Medical Officers' Club in Bethesda, Maryland and generally last until 1330 hours. One of the food items expected by the Club Staff to be ordered but never fulfilled , is fresh goat milk. Frequently we are greeted with, "Sorry, no goat milk today".

Of the wide range of management, reproductive, and genetic engineering problems and solutions considered at our luncheon meetings, no problem has been of greater importance to Clair Terrill than efficiency of production. Most luncheon meetings either begin or end with efficiency on his mind. Clair is passionately devoted to improving the economic position of the American Farmer through sound pragmatic research on efficiency, whether management, genetic, reproductive or predator control.

In a recent article in Sheep ! magazine, James Innes had this to say: "There are many excellent scientific people working in the sheep industry. Some of these people are leaders in their respective fields. But unfortunately, a lot of this work is not really of much use to the industry in its present state." This statement by a seasoned sheep stockman should not be taken lightly. The message Innes is conveying here is that more research thought should be directed toward that which farmers can use to achieve more efficiency in production and hence greater return on the agricultural dollar and effort. Clair has addressed this over and over again at our work sessions.

Alexander Smith once said, "The great man is the man who does a thing for the first time" (Bartlett, 1955). To illustrate that point, Clair initiated his efficiency idea years ago in the breeding program studies he began at the USDA. Recently he has brought the data together to show the increased efficiency and profit margin accruing to farmers in the Northwest as a result of the stock produced by these measures at the U.S. Sheep Experiment Station at Dubois, Idaho (Terrill, 1989). This is the kind of work Innes had in mind in his article in Sheep ! magazine, as the sort that should be done.

Clair seems never to slow down. A frequent traveler to every continent, he is always seeking ideas, expanding his own perceptions and expounding on programs of breeding efficiency. At nearly 80 years young, he is a dynamic model for all of us.

He frequently meets with Congressmen and Senators and provides expert testimony at congressional hearings on predator control. He gives his time and energy and emotions generously and often. A notable example is the support he gave to a shepherdess in the Shenandoah Valley after a terrible flood had destroyed much of her farm and her flock of sheep and taken the life of her husbsnd.

Here is a kind, gentle man whose thoughts are never far from the American Farmer, civilized to a fine degree, thoughtful always of others, diffident, unassuming, steady as a rock.

I am honored to call him **Friend.**

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Twenty years ago Dr. Lincicome retired as Professor of Parasitology at Howard University. For the past 12 years he has served the USDA as Guest Scientist at the Agricultural Research Center, Beltsville, Maryland.

CLAIR TERRILL'S LIFE ON THE FARM

Lurene Irwin

Clair and I were born on a small farm in Greene County, Iowa. It had the rich, black soil of Central Iowa and probably was wet and needed tiling. Clair was born in 1910 and in 1912 our parents bought a livestock farm 25 miles south in adjoining Dallas County. Their goals were to buy land in a town school district so their children would be eligible to attend a town school. Our mother was a country school teacher and she knew the limitations of a one room rural school often with one teacher, 25 to 30 pupils, and all eight grades. Their second goal was to have a livestock farm with good pasture, a reliable source of water, and some cropland. They found the pasture, and the water, but the cropland was more limited. The land was not as productive as Greene County and more limited in amount.

Nevertheless we had a happy and expanding existence here for ten years. Our parents bought more cropland. Livestock was increased to over 10 Guernsey milk cows, a flock of sheep, purebred Tamworth hogs and of course the requisite number of work horses.

Clair started to milk when he was in fourth grade and before long was doing everything with livestock that a man could do except harness the horses. He needed to be taller to accomplish that task.

It was the golden age of farming and as early as 1919 our father acquired a Fordson tractor. This was not common practice. The big wave of tractor technology would really begin after World War II. By that time our father farmed with a sturdy Farmall tractor.

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The Redfield farm was a children's paradise. We knew where all the wildflowers grew in the spring, where to find the wild strawberries, gooseberries, and raspberries in the summer, and in the fall there were wild grapes, hickory nuts, walnuts, hazelnuts, and the red haw tree. In the winter we skated on the pond and when the pussy willows came we knew spring was on its way. We dammed up the two small streams that crossed the farm and waded in the cool water. And even though the folks bought their first car in 1916 we walked everywhere. We walked to school, to town, to church, and to the neighbors. I thought nothing of walking two miles each way for my violin lesson.

I longed for a pony which I never got but later our younger brother, Marvin, had a Shetland pony. I think we all got as big a thrill from it as he did just to see the fun he had. Clair's wife, Zola, did have a pony which she loved and rode expertly. When they went away to graduate school, Sparkle ended her days on the farm with my husband and I. I rode her when I could catch her but never as expertly as Zola did.

In 1923 a major change in our living and in our farming took place. Our grandfather died and it was decided we would move back to the home place where our great grandfather had come in 1868. Clair was 12 years old and about to begin doing a man's work. My great grandfather formed with six oxen. We would farm with a combination of horses and a tractor.

Typical of our parents zeal for education we moved not on March 1st but in January. We would move between the two semesters so that our school work would suffer the minimum disruption.

It was fifteen below zero when we moved the 25 miles back to Greene County. Clair and his uncles drove the livestock that 25 miles in two days. It was so cold that Clair's sandwiches froze so solid they could hardly have been broken with a pick axe. We missed just two days of school. Clair says he does not

remember ever staying out of school to work. This was common in farm families at that time but not in ours.

Our life changed in many ways. We no longer walked. It was too far to town - six miles. We left a large consolidated school at Redfield - a school which my father had helped organize. We walked to this school many times in preference to riding the bus. Now at Rippey we rode the bus.

We missed the easy availability of water. Now we had two windmills and a large supply tank from which the water flowed by gravity to a large stock tank by the barn. The growing numbers of livestock took huge quantities of water and when the wind did not blow we were in trouble. Clair remembers pumping water by hand all day and our father in turn pumping water all night in order to have enough for all the thirsty animals.

Our work multiplied in other ways. The cropland doubled and Clair's work in growing crops multiplied also. He remembers harrowing, cultivating with a walking cultivator, then driving a two row cultivator with 3 horses. There was hay making which progressed from driving the rack, to pitching up the hay, to arranging it on the rack, to its final destination to the barn or stack.

Our father, who had helped organize a threshing ring where he operated a steam thresher at Redfield, now owned a gas powered threshing machine for the threshing ring at Rippey. Clair says some of the hardest work he ever did was during the summer of 1932. He was newly married, had just graduated from Iowa State and he and Zola would leave that fall for graduate study at the University of Missouri. It was the depression and there was no money to hire any help. Again our father and Clair sometimes worked all night under the tractor by lantern light in order to have the machine repaired and ready to go the next day. Clair said that summer often found each of them trying to do the work of two men. One thing that helped were the two younger brothers coming on to assist. Stanley was now 14 and Marvin 11 and they could do alot. Our youngest brother had died at the age of four years.

Meanwhile we operated without electricity. The electric utilities regarded rural service as a money loser and put many obstacles in the way. Clair remembers shaving and moving the lamp from one side to the other in order to shave both sides of his face. Our father put forth great effort to obtain and increase the REC in Greene County. Clair and I were both gone from home before we got electricity in 1937. Our father served on the initial board of directors and served until his death twenty years later.

I asked Clair when we got our first milking machine (a gas powered unit) and he replied, "The year I went to college and that was also the year they bought the hay loader." Change was on its way but who could guess that one of the topics at the Central Iowa Farm Business Association only 15 years later would be "How to persuade Father to plow up the horse pasture", that there would be 12 and 16 row corn planters, that the threshers would give way to the combine, and corn would be picked by machine.

Though Clair and Zola have travelled afar, the farm has always remained a central part of both their lives. Today all the buildings on all these farms have all disappeared - the little farmhouse where we were born, the buildings on the farm at Redfield - some of them built by our parents, and the buildings on the home place - some built by our great grandfather, added to by our grandfather, and a few more added by our parents but the land remains. The land remains still in the family and still very much a central part of our lives today.

GRADUATE STUDENT

Marshall C. Heck

I would like to speak as a college student working with Dr. Terrill.

I received an N.Y.A. job working in the Animal Husbandry Department of the University of Missouri in the Fall of 1934. Soon after starting to work I was called into the office of the late Dr. Albert Dyer. He asked me if I would like to feed sheep. I said I would. I was asked to worked for Dr. Terrill and other graduate students working on their research projects. To feed the sheep I had to arise at 6:00 A.M., walk about one half mile to the "long shed". I had to rush to make an 8:00 A.M. class.

I also worked in the laboratory in Switzer Hall. I counted abnormal spermatozoa using a low power microscope and a hemacytometer.

I remember vividly one task in the laboratory. Dr. Terrill was probably the first to film the ovulation of a ewe. As a student worker my job was to anesthetize the animal. I poured liquid ether from a pint tin can onto a cloth sponge held over the nostrils of the ewe. I almost anesthetized myself, but when the follicle ruptured and the egg came out Dr. Terrill was there with his camera to get it on film.

Dr. Terrill has made a great contribution to Animal Agriculture and particularly to the sheep industry of this country and the world. He has been an inspiration to all who have worked with him.

Congratulations Dr. Terrill. It has been a pleasure to have known you for 55 years.

CLAIR TERRILL AND THE USSES

Charles F. Parker

Clair Terrill began his professional career at the U. S. Sheep Experiment Station near Dubois, Idaho, in 1936. This young Scientist and wife Zola spent the next nineteen years at this location. Dr. Terrill received his Ph.D. at the University of Missouri conducting basic investigations on the reproductive physiology of the ewe. With his advanced education and practical livestock background, he established a strong scientific approach for research with sheep at the USSES.

Clair Terrill was responsible for initiating many innovative programs at the sheep station. Fertility testing of rams, studies with artificial insemination and evaluation of live body weight advanced the understanding of reproductive performance in range sheep. The development of inbred lines with subsequent evaluation provided the most comprehensive data set for determining the importance of inbreeding with sheep of any location in the world.

Dr. Terrill's collaboration with Dr. Hazel at the USSES initiated the scientific approach for the genetic improvement of sheep. Advanced statistical procedures were developed and used to estimate genetic parameters for many economically important traits. These studies resulted in breeding plans that included index selection for genetic improvement. Genetic environmental effects and their associations were studied and related to the economic importance of selecting fine wool sheep with open face, smooth bodied and longer staple length. The national importance of Columbia and Targhee breeds developed at the station was enhanced through the efforts of Dr. Terrill.

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Selection studies were initiated with control groups by Clair Terrill in the late 1940's. Subsequent performance of these lines has contributed significantly to understanding the importance of selection, especially for improving reproductive efficiency and aseasonal breeding.

Through the early research leadership of Dr. Terrill the U. S. Sheep Experiment Station has become recognized as a major resource for discovery and development of technology for improving sheep production throughout the world. Clair Terrill has inspired many of us with his extraordinary dedication and enthusiasm for sheep. His scientific contributions during his time at the U. S. Experiment Station are many and have greatly improved the efficiency of sheep production.

CLAIR E. TERRILL - HIS PROFESSIONAL ACCOMPLISHMENTS

Gary L. Cromwell

Clair E. Terrill, the 1989 recipient of the Saddle and Sirloin Portrait Award, has been an enthusiastic leader and an effective spokesman for the sheep industry for over 50 years. He has contributed significantly to the sheep industry by conducting and directing research designed to increase the efficiency of lamb and wool production. Dr. Terrill is recognized internationally for his accomplishments and support of the efficient production of lamb meat and wool fiber. Though retired for nine years, he still is active in promoting the sheep industry throughout the nation and the world.

Dr. Terrill is a native of Iowa. He was born near Rippey, Iowa in 1910 and was raised on a livestock farm. He attended Iowa State University and graduated in 1932 with a degree in Animal Husbandry. His graduate work was in Animal Breeding at the University of Missouri, where he received the PhD in 1936. His research involved basic studies on ovulation and reproduction in the ewe.

Dr. Terrill began his professional career at the Georgia Experiment Station. He later accepted a research position at the USDA Sheep Experiment Station at Dubois, Idaho. After 17 years of research in sheep breeding, he became Director of the Experiment Station in 1955. In 1957, Terrill moved to Beltsville, Maryland where he became Chief of the Sheep and Fur Animal Research Branch of the Agricultural Research Service of the USDA. He served in this position until 1972. Subsequently, he was appointed National Program Leader for Sheep and Other Animals with the Agricultural Research Service of USDA. Dr. Terrill served in this capacity until retirement in 1981.

Dr. Terrill's brilliant research career has covered nearly all phases of sheep and wool production. His most significant research has involved studies on ewe and ram fertility, development of inbred lines and breeding systems, and predator control. Much of his research involved the application of basic reproduction and breeding principles to practical sheep production. He pioneered in breeding open-faced sheep, showing that open-faced ewes produced more lambs. He was one of the first to promote the use of ram lambs for breeding which accelerated gains from selection. He is credited as being one of the founders of the Targhee breed of sheep. Terrill developed a reliable and practical measure of determining losses from predators in the sheep industry in different states, using USDA mortality data. His work focused attention on the effects of predator losses on the decline in sheep numbers and the declining efficiency of the sheep industry. His work showed that toxins could be used effectively to control predators without significant damage to wildlife, endangered species, people or the environment.

Although retired, Dr. Terrill still is very active in his field of expertise. He collaborates regularly (without compensation) with the National Program Staff of USDA, presenting ideas, writing papers and reports and serving in a number of other capacities focused at increasing the efficiency of production of sheep, goats and other animals on a national and international basis.

Dr. Terrill has been an active member of the American Society of Animal Science (ASAS) for 57 years. He served the Society as President of the Western Section in 1951. Later he was elected as Secretary-Treasurer and Business Manager, Vice President, and in 1964 became President of the American Society of Animal Science.

During Dr. Terrill's tenure as President of the Society, many important and lasting changes took place. Dr. Terrill was responsible for establishing the program committees for the various species groups (i.e., beef cattle, dairy cattle, swine, sheep and horses) at the national meeting. He further proposed that these sessions be held at times when they would not conflict with other sessions. Dr. Terrill pointed out that this would encourage scientists working in different disciplines, but with one species, to assemble and discuss mutual problems together. Terrill felt that species sessions would tend to crystallize ideas on important problems in the different classes of livestock and would provide an additional vehicle through which the Society could exercise greater leadership in the livestock industry. Dr. Terrill's idea on species sessions was adopted by the Society in 1965, and these sessions continue to be among the most popular scientific sessions at the ASAS annual meeting.

During the years that Dr. Terrill served as Vice-President and President, the annual meeting of the Society was changed from a single location (Chicago) to university campuses throughout the country. The Midwestern Section of ASAS was organized and implemented during his tenure, in 1963. This change allowed scientists to present a much greater number of research papers to national and regional audiences. Dr. Terrill felt strongly that delivery of new scientific information was one of the major functions of the Society. Today, the Midwestern Section of ASAS has the greatest number of members of the four sections in the Society.

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The Journal of Animal Science changed to the metric system during his tenure. A change was made in the method of electing officers in the Society, so all members could vote by mail ballot instead of the voting being done only by those people who attended the annual meeting.

Dr. Terrill was, and still is, a strong supporter of international agriculture. While serving as a national officer of ASAS, he played an important part in organizing the first World Conference on Animal Production in Rome in 1963. He encouraged the membership of ASAS to develop research programs using farm animals, such as pigs, sheep and rabbits, as models for human research.

Dr. Terrill served on the Editorial Board of the Journal of Animal Science from 1954 to 1957. His first research paper, "Estrus and Ovulation in the Ewe," was published in the 1935 issue of the Proceedings of the American Society of Animal Production, the forerunner of the Journal of Animal Science. He has the distinction of having one of his papers, "The Importance of Body Weight in Selection of Range Ewes," published in the very first volume of the Journal of Animal Science, in 1942.

Terrill has travelled in every state of the Union, sharing his knowledge about sheep with producers and scientists. In addition, he has appeared on programs in 53 foreign countries, as many as nine times in some countries, exchanging information with others on methods of improving the sheep industry. He has published his findings in numerous scientific publications, conference proceedings and book chapters.

He has been a member of 28 scientific societies during his career. He was given the ASAS Fellow Award in 1969, and the Animal Industry Service Award in 1981. Other awards, too numerous to mention, have been bestowed on Terrill. One of the most significant was the Silver Ram Award, the highest award granted by the American Sheep Producers Council for outstanding accomplishments and service to the sheep industry.

Dr. Clair Terrill has had an illustrious and enviable career in animal agriculture. Even today, when scientists and leaders of the sheep industry think of sheep, one of the first names that comes to mind is Clair Terrill. It is an honor to have an enthusiastic and devoted person of such high caliber to be named as the recipient of the Saddle and Sirloin Award for 1989.

CLAIR E. TERRILL - A SCIENTIST AND ADMINISTRATOR

A. L. Pope

Clair Terrill's interest in science began on his boyhood Iowa farm. His first Smith Hughes project, while in high school, compared hybrid and open-pollinated corn. As a graduate student at the University of Missouri, his primary interest became livestock. There his basic studies on reproduction in the ewe are still referred to by scientists in this field.

From the beginning of his professional career, he had one objective. His research results must be of direct and immediate benefit to farmers. And, this goal has always been more important to him than benefiting himself as a scientist.

Fifty years ago when Clair Terrill began his work at the U.S. Sheep Experiment Station, Dubois, Idaho, he saw that genetic selection for productive efficiency could increase the net return to ranchers. This he achieved by selling to the ranchers research improved rams produced under rigid selection guidelines. Later, he developed breeding principles and selection indices that resulted in improved efficiency throughout the United States. He and his coworkers developed selection programs that would increase weight of lamb weaned per ewe by about 2% and net returns by as much as 10% per year. He has documented the hundreds of millions of dollars in increased net returns to sheep producers from the selection research at Dubois.

But, his interests extended beyond sheep breeding research because he was first of all interested in "sheep". While he served as Chief, Sheep and Fur Animal Research Branch, Animal Science Research Division of the Agricultural Research Service, USDA, he directed all federal research with sheep. Under his direction came the introduction of artificial rearing of lambs, pregnancy diagnosis, management to aid in control of internal parasites, chemical shearing, the highfertility Finnsheep, crossbreeding to increase the reproductive rate and selection for year around lambing.

As an administrator, he lead by example. He was always considerate and fair. I first met Dr. Terrill in 1946 when he worked at Dubois. I had stopped in unannounced. Although I was only a fresh Ph.D. whom he had never met, he spent most of the day showing me the facilities, introducing me to the staff and discussing sheep research. He has treated all visitors similarly over the years, both there and later at Beltsville.

Two examples of his fairness are typical: He was one of the very first to recognize the benefit of the Finnish Landrace breed in improving the prolificacy of sheep in this country. The problem was to get sufficient numbers of the breed. As he acquired numbers at Beltsville and elsewhere, he was careful and fair in distributing them to State Experiment Stations across the United States so that they would not be concentrated in the hands of a few. Likewise, he was enthusiastic in distributing cyclophosphamide and information to any interested scientist so that research on chemical defleecing could be accomplished. Science would not have benefited if he had wanted to selfishly conduct the work himself for his own recognition.

Another example of his keen desire to spread scientific knowledge for the benefit of the industry was his organization of the Symposium on Management of Reproduction in Sheep and Goats held three years before his retirement. He saw the need and then tirelessly and successfully sought financial support, organized the program, invited the eight foreign speakers and saw that the proceedings were completed and published. It was a tremendous job and could only have been done by someone whose one goal was service to an industry.

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Unlike many scientists, Clair Terrill has maintained his grass roots connection with farmers and ranchers. He has regularly attended the National Wool Growers Convention. When he has learned of producer problems, he has done something about them. Thousands of sheep raisers know him and speak of him as a personal friend. He has made a difference. This was confirmed when the industry selected him for their Silver Ram Award; the first from the educational field.

And, Clair Terrill still contributes his energies to the industry and to science. Seven years after retirement he presented a research paper at the American Society of Animal Science Annual Meeting in 1987. This consisted of data analysis of ram performance of Dubois Station rams used by ranchers. In 1987 he attended an International Sheep Conference in Iceland to present a paper and the North Central Meeting of Sheep Researchers at Medora, North Dakota. In 1988, he attended the World Conference on Animal Production in Helsinki, Finland. At the 1989 Western Section of the American Society of Animal Science, Bozeman, Montana he presented a paper, "Impact of Selection Research on Efficiency of Production of Lambs and Wool." He continues to write articles for sheep magazines.

In summary, it is important to acknowledge Clair Terrill's tremendous enthusiasm for the future of the sheep industry. This industry has had more than its share of problems. But, Clair is always looking on the bright side. He has prepared data and evidence to show that the ruminant of the future is the sheep, that sheep numbers in this country will be turned around as predator damage is controlled and energy conservation and efficient forage utilization become top priorities. No one has surpassed him in enthusiasm, dedication, sincerity and hard work.

CLAIR E. TERRILL
A COLLEAGUE AND A FRIEND

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I first met Clair in the fall of 1951, 38 years ago. I was new on the faculty at Montana State and at that time it was customary for Experiment Station staff in the states surrounding Dubois to assist with collecting experimental data on the lambs at weaning time. Clair was in charge of collecting that data and I remember getting awakened at 4:00 AM with the announcement that breakfast was waiting. With our stomachs warmed and our spirits encouraged we set out for the Forest Service allotments on the divide near the Idaho-Montana border where the sheep had summered. During that day we weighed and scored each lamb individually from an entire band of sheep. Our work was sporadically interrupted by some rain or snow squalls as well as some time out to warm our hands around a bonfire or drink some coffee. The whole procedure went like clockwork, evidence Clair had looked after every little detail. Clair was friendly and very outgoing, giving us an opportunity to ask him some questions about the Station program, about selection indices and sheep improvement. I learned much about sheep improvement studies being done at the Station and was very impressed. Regarding some of the questions being asked there was no reluctance on his part to notify us he didn't know if that was the case. That in my opinion was a mark of greatness. Having completed our work for the day we descended to the station and then back to Bozeman. The next week found us back at the station assisting with another band of sheep and this performance was repeated each fall for several years. On the second year back to Dubois, Clair was Director of the Station. Other visits to the Station were during their annual sheep sales. Many times Montana producers with whom I was acquainted asked me to accompany them and look at the records of specific sheep they were interested in purchasing. Many of these producers had purchased rams from the Station for years and they were interested in their selection index. They expressed a satisfaction with their purchases at the station and were there to bid on the best. I marveled how producers accepted these evaluation tools so readily and spoke so highly of the work being conducted at Dubois. This was the kind of research an individual producer could not do on his own, nevertheless each producer who bought rams and ewes from the Station was capitalizing on that research. This is just one example of the research that Dr Terrill was responsible for establishing and conducting?

Some years later the Sheep Station under Clair's direction sought the cooperation of the Montana Experiment Station in testing rams from their inbred lines on the band of Experiment Station ewes. They wanted to progeny test these high indexing, inbred rams on unrelated stock and evaluate their offspring. I remember well when the rams arrived from Dubois. They sent records on all the rams including type of birth, index score, etc. They also had evaluated semen from most of the rams but there were a few that would not cooperate. A few of the rams in the group were relatively small and seemed to lack vigor. I wasn't too concerned about that unless the rams didn't have libido thus not breeding the ewes. Tom Drummond, a shepherd at Montana, wanted me to come with him and look at the rams. He said to me,"you don't plan to use all these rams in the breeding pens do you?" I said "that is the plan". "Well how about that one, he seems to be awful small and I wouldn't breed him to any of my ewes". I indicated to him we

should look at the records to learn more about the rams. The rams in question were usually the most highly inbreed, were born and raised twins and in some cases were born later in the season. This specific ram had a very high inbreeding coefficient and was a late twin. Geneticists have amply demonstrated that inbreeding has a negative impact on type (conformation), vigor and growth. I indicated to Tom Drummond that the proof was in the progeny test whether that ram was outstanding in breeding performance or at the worst a cull. He had no hesitation to inform me that we shouldn't use those rams in spite of my attempt to convey to him my confidence in the geneticists at the U. S. Sheep Station and that all would turn out much better than the gloomy picture he was painting. The rams were put into the breeding pens and I looked forward to next year at weaning time when we could cut out the lambs by sires and then observe the offspring.

Weaning time came and the crew from Dubois arrived to assist with weighing and evaluating the lambs. With that accomplished we separated the lambs by sire pens and looked at all the offspring from each ram. I had kept record of the individual rams that Tom Drummond objected to. I called him to have a look at the lambs this year. We walked by all the sire pens and he said the lambs looked good this year. I then said I wanted to look at three specific pens again and we went to the pens from the rams that he had rated culls. He liked the pens of lambs and then I reminded him these three pens were the offspring of those rams he had objected to using the previous November. He said to me "there is no way I am going to believe that". I expected a demonstration of hybrid vigor in the offspring of the rams in question but I must admit the lambs were even better than I had anticipated.

Shortly after these progeny testing studies Clair moved to a different range and a different watering hole, the federal compound back east. Subsequently I also left Montana for points west but I always kept in contact with Clair often seeing him at the Western Section or the National Animal Science meetings. Finally I find myself also back east on different Government range but fortunately we do at times get together at the same watering hole.

As a colleague and a friend of Clair's I want to convey my admiration for him and the work he has accomplished. Clair had a great deal of foresight back in the early years when he established the breeding trials designed to improve production efficiency of sheep, particularly on the Western foothill ranges. Breeding studies tend to be long term thus the need for careful planning, careful data collection and evaluation and patience for years of results prior to evaluating improvement. Most researchers today don't want their pie in the sky sometime in the future, they want it in their hand and right now. Clair is an optimist and is continuously thinking of utilizing sheep in areas where the vegetation is not being utilized to its maximum. Clair is a friend of sheep producers and scientists throughout the US as well as internationally. It is not uncommon while travelling abroad and in the company of researchers working with sheep to be asked if one knows Clair. In letters from donors supporting this award there were many handwritten notes to greet Clair and that he was very deserving of this recognition. It has been my honor to be associated with a person who has accomplished so much and is held in such high esteem by the industry which he worked for and the scientists who were his colleagues and friends.